BUSINESS CYCLE SYNCHRONIZATION BETWEEN THE EURO AREA AND THE CENTRAL AND EASTERN EUROPEAN COUNTRIES MEMBER STATES OF THE EU: A MARKOV SWITCHING REGIME MODEL APPROACH

por

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Vita

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He graduated in Economics from *Faculdade de Economia do Porto* (FEP) in 2002 and, two years later, in Management from the same college.

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In early 2006 he started his career in *API – Agência Portuguesa para o Investimento*, currently named *AICEP – Agência para o Investimento e Comércio Externo*, where he deals with *PIN* projects (*Potencial Interesse Nacional*), assisting investors in overcoming legislative barriers.

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"*A verdadeira descoberta não consiste em procurar novas paisagens, mas sim em ter novos olhos*"

Marcel Proust

Abstract

This dissertation assesses the degree of business cycle synchronization between the Central and Eastern European Countries (CEECs) that have become part of the European Union (EU) in 2004 and 2007 but still not the Euro Area. This assessment intends to shed light on the capability and desirability of integration of these CEECs into the Euro Area.

The motivation for the analysis in this dissertation originates in the Optimum Currency Area (OCA) literature, which brings about a somewhat different set of conditions for joining a currency area than those prescribed by the European Union Treaty (generally known as Maastricht convergence criteria). One of the OCA criterion relates to the symmetry of business cycles between the potential members of a currency area: the bigger the symmetry, the more likely it is for a country to reap net benefits from joining in.

In order to assess that symmetry, in this dissertation we measure the degree of synchronization between the business cycles. The measures of synchronization presented here follow the lines of Harding and Pagan (2002a), who describe a business cycle by means of computing and assessing its turning points, in the context of a classical definition of the business cycle (rather than a *deviation cycle* definition). The related literature offers two essential means of detecting turning points: one based on non parametric methods, such as the one suggested by Bry and Boschan (1971); the other using parametric nonlinear models such as the Markov Switching Regime model.

This dissertation follows the latter of these alternatives. This choice is motivated by the fact that there is no evidence, to the best of our knowledge, that this specific approach has been followed for studying this problematic for this particular set of countries.

The literature of business cycle convergence between CEECs and the Euro Area has divergent results, apparently due to the use of different data sets, different methods of business cycles identification, and different methods for assessing convergence.

In this dissertation, having chosen specific methods for identification of business cycles and their convergence, we perform some sensitivity analysis to the data, using the elected approach on two time series of real economic activity, the real Gross Domestic Product and the Industrial Production Index. The results are homogenous in the sense that the business cycles of the same group of countries have been found to be synchronized with the Euro Area’s cycle: Hungary, Poland and the Slovak Republic.

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1 Introduction

Ten years after the introduction of the Euro into the lives of 300 million people one may say that this unprecedented economic endeavour has been a success. Price stability, low and stable inflation expectations, low long term interest rates and financial integration are some of the accomplished goals of the European Monetary Union (EMU).

All the Central and Eastern Europe Countries (CEECs) that have acceded to the European Union (EU) in 2004 and 2007 are currently being encouraged to fulfil the convergence criteria established in the European Union Treaty as conditions for adopting the Euro – known as Maastricht criteria –, especially because they do not have any opt-out clause. Given the fact that becoming part of a single currency area implies the loss of monetary policy as a domestic adjustment tool, these criteria essentially ensure macroeconomic stability. As is well-known, they involve: i) small inflation differential regarding the three best performing EMU members; ii) a period of stability of the nominal exchange rate against the euro; iii) sound fiscal accounts (deficit and debt) and iv) low long term interest rate spread relative to the three best performing EMU member states in (i).

Well before the institution of the nominal and rather quantitative Maastricht criteria for the EMU case, the theoretical and empirical discussion of the integration of a country into a monetary union has been conducted within the cost-benefit analysis known as the Optimum Currency Area (OCA) literature[1]: if a group of partner countries achieves a certain number of pre-conditions then currency unification will result in net gains for each and all, as benefits surpass the costs.

The benefits include, essentially, the welfare gains resulting from higher trade and financial integration, resulting from the decrease in international transaction costs and nominal risks.

[1] Mundell (1961) was the precursor of the OCA theory.

The cost typically mentioned relates to the fact that countries lose a stabilizing tool – monetary policy – thus being unable to use macroeconomic policy to dampen business cycle fluctuations. As Camacho *et al.* (2008, page 2166) state that it may happen that "if the shapes of their cycles are different, supranational policy reactions against recessions may be too accommodative for countries that change the business cycle phases sharply and too tight for countries whose state changes are smooth. These policies may also last too long for countries with shorter duration of cycles and too short for countries with longer cycles. Finally, the strength of common stabilization policies may be insufficient for those countries with deeper cycles and disproportionate for countries with mild cycles".

This is, precisely, one of the conditions that need to be satisfied, according to the OCA literature, for benefits to exceed costs in monetary unification: countries with symmetric cycles are more likely to obtain a net benefit from a currency area. Studying this pre-condition is all the more relevant as the Maastricht criteria are purely nominal and do not include similarity of real economic fluctuations.

The other main conditions – which are not studied in this dissertation – relate to the intensity of trade, labour mobility, and fiscal transfers, between the countries that are to form a currency area.

De Grauwe and Mongelli (2004) show quite simply the importance of the degree of economic integration and the symmetry of shocks for the evaluation of the net gains from entering a currency union. As displayed in Figure 1-1 there is an OCA line corresponding to the set of combinations of integration and cyclical symmetry along which the gains and costs of joining the currency area break even.

An increase in asymmetry elevates the costs of having lost the national monetary policy by joining the currency area. On the other hand, a country may reap benefits from an increase in integration. The combination of these two considerations helps to explain why the OCA line is downward sloping: above the OCA line represents an area where benefits exceed costs, and vice-versa.[2]

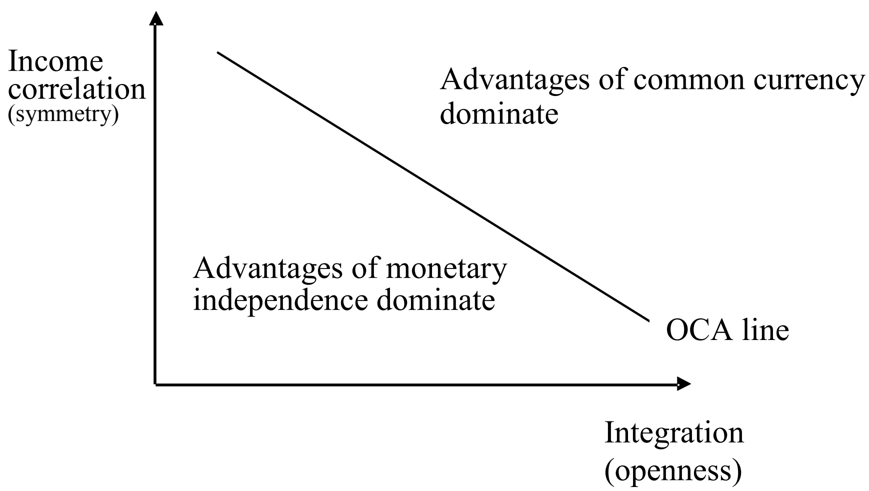

Figure 1-1: Symmetry, integration and OCA

Assessing how much (a)symmetric are the business cycles implies measuring their synchronization and essential characteristics. The purpose of this dissertation is to conduct such an analysis in the case of the CEECs, thus contributing with extra information, on top of that relative to the Maastricht criteria, on the capability and desirability of the CEECs joining the euro zone on the basis of the information available at this moment.

. The measures of synchronization presented in this dissertation follow closely the analysis by Harding and Pagan (2002a), who describe a business cycle by means of assessing the turning points in a time series of a variable representative of the level of real aggregate

[2] We are well aware of the discussion of the endogeneity of the OCA conditions, but choose not to explore it in this dissertation, which is more limited in its scope. As a recent example, Christian Noyer, the Governor of the Banque de France, has stated at the GIC/Drexel Spring 2007 Conference entitled “From Maastricht to the present and beyond” that “monetary union is a self sustaining process: convergence can be a result, as much as a condition of economic integration”. The optimistic view on currency unifications, which highlights that the pre-conditions of the OCA theory are reinforced once the OCA space has been created, is not new. Frankel and Rose (1998), for instance, argue that cutting down transaction costs and removing trade barriers not only raises trade, but also allows demand shocks to spread across the trading members, leading to more correlated business cycles.

economic activity. This approach, based on the detection of cycles in the (log) levels of such a time series, is usually known as the *classical cycle* approach -- as opposed to the study of time series computed by extracting cyclical information through some filtering of the original series, known as *deviation cycle* approach.[3]

Within the *classical cycles* approach that we pursue, there are in the literature two basic methods for detecting the cyclical turning points: one alternative relies on non parametric methods, such as the algorithm suggested by Bry and Boschan (1971); the other alternative uses parametric models such as the Markov Switching Regime model. With the purpose of contributing to the literature, this dissertation follows the latter, as there is no evidence, to the best of our knowledge, that this specific approach has been followed for the particular set of countries that we study.

As is well-known – see, *inter alia*, Smith and Summers (2005) – the estimates of the timing of regime changes computed by Markov Switching (MS) Regime models allow for the definition of business cycle chronologies, based on the identified turning points, which can subsequently be used to assess synchronization. The non-linearity of MS regime models is an important advantage of this approach, as they hence capture the well documented fact that there is asymmetry between expansions and contractions in the typical behaviour of modern economies.

The conventional wisdom is that economic cycles in the most advanced CEECs are highly correlated with the Euro Area. In our literature review we have confirmed this perception, especially in the case of Hungary. However, we have also found that the results are mixed. This divergence of conclusions about the degree of synchronization in a variety of papers

[3] Artis, Marcellino and Proietti (2003) present a somewhat different distinction between classical and deviation cycles, since they define deviation cycles' turning points as changes in the deviation of the rate of growth of GDP relative to a defined trend rate of growth (maintaining the definition of classical cycle turning points on the basis of an absolute rise (or decline) of GDP).
The most important comparative study of the numerous methods for extracting deviation cycles is still Canova (1998), who has shown that different filtering methods would provide different conclusions regarding the business cycle for the United States.

may be explained by the use of different data sets, different methods of identifying business cycles, and different methods for assessing their convergence. In this dissertation we do not aim at comparing the results of different empirical methods. Rather, we provide some robustness check of our results by submitting both the real Gross Domestic Product (GDP) and the Industrial Production Index (IPI) to the methods of identification of cycles and gauge of their synchronization that we have chosen to work with.

The rest of the dissertation is organized as follows. Chapter 2 and 3 review the literature on business cycle synchronization and Markov Switching regime models, respectively. Chapter 4 performs all the empirical analysis regarding the estimation of the Markov Switching regime models and the business cycles synchronization. Chapter 5 closes the dissertation, presenting a global summary of our results and some concluding remarks.

2 Business Cycle Synchronization: an introductory overview

This chapter aims at reviewing the literature on business cycle synchronization that is relevant for this dissertation – which, as mentioned in the previous chapter, is the *classical cycle* approach. We start by clearly defining and characterizing the business cycle, in section 2.1. Section 2.2 then discusses which time series should be studied in order to detect business cycles. Section 2.3 presents two basic different solutions to determining the turning points of the chosen time series: parametric and non parametric perspectives. Since we opt for the latter, and more specifically the Markov Switching (MS) regime models, the subsequent chapter will further develop this approach. In section 2.4 we summarize a number of the main indicators of synchronization appearing in the relevant literature.

2.1 Defining and Characterizing a Business Cycle

Burns and Mitchell (1946, page 3), who have pioneered the analysis of business cycles in the 20th Century, defined a business cycle (BC) as a pattern in a series Y_t representing the aggregate economic activity, consisting "of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle". The BC is, thus, a broadly based movement of economic variables in a sequentially oscillatory manner, as Artis *et. al* (2003) have put it.

Beyond the apparent simplicity of the basic definition presented in the last paragraph, Burns and Mitchell (1946) defined nine items that would provide a thorough identification of a BC. More recently, Harding and Pagan (2002a) have summarized those items in three relevant features: length, depth and shape. As recently explored by Camacho *et. al* (2008), these may be approximated by measures of duration, amplitude and excess, respectively.

Figure 2-1 – sourced from Camacho *et al.* (2008, page 2169) – graphically presents these concepts in a quite intuitive way. It starts from the idea that one can think of the phase of a cycle as a triangle, in which the base represents *duration* and the height represents *amplitude*.

Regarding *length*, the *duration* of an expansion (recession) corresponds to the time spent between the through (peak) – which marks the end of a recession (expansion) – and the following peak (through) – which marks the end of an expansion (recession). These two states are delimited by turning points (minima and maxima), and their listing provides a business cycle chronology [see also Giancarlo and Otranto (2008)].

Comparing the log level of the series at two consecutive turning points allows measuring the *amplitude* of the expansion or recession.

The last feature of the business cycle is its shape. With this regard, Harding and Pagan (2002a) defined *excess* as the measure of the abruptness with which the time series enters to and exits from its turning points. As Camacho *et. al* (2008) put it, in practice, *excess* compares the actual time series path from the hypothetical path if the transition between two consecutives turning points was linear.

Thus, *excess* is clearly an approximation to the second derivative of the series, and allows for examining the concavity or convexity of the business cycle phase: convex (concave) actual paths are characterized by positive (negative) measures of excess, as represented by the shaded areas [Camacho *et. al* (2008)].

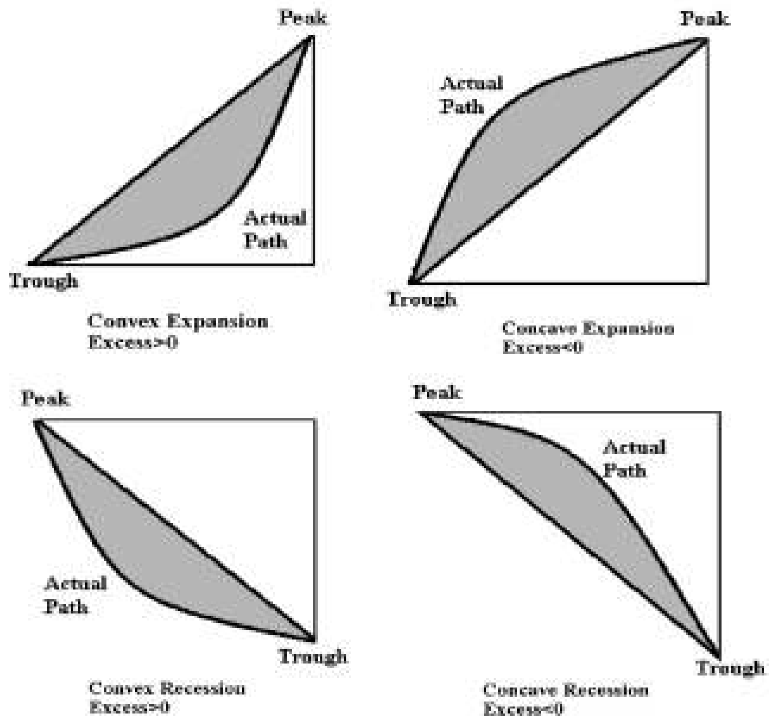

Figure 2-1: Duration, amplitude and excess.
Notes: 1. Stylized representation of typical expansions (top charts) and recessions (bottom charts).
2. Source: Camacho *et al.* (2008, pg 2169)

These measures have been used in recent research and will also be used in our quantitative assessment in chapter 4.

Implementation of these measures implies a previous computation of a binary series $S_{i,t}$ with value one at recessions and zero at expansions – see the next sections on how to compute this latent variable. Then, the following statistics will be used [Altavilla (2004)]:

$$D_{TP} = \frac{\sum_{t=1}^{T} S_t}{\sum_{t=1}^{T-1} (1 - S_{t+1}) S_t}; \qquad D_{PT} = \frac{\sum_{t=1}^{T} (1 - S_t)}{\sum_{t=1}^{T-1} (1 - S_t) S_{t+1}}$$

D_{TP} and D_{PT} measure the average duration of the expansionary and recessionary periods, respectively, where *TP* denotes trough-to-peak and PT stands for peak-to-trough.

$$AMP_{TP} = \frac{\sum_{t=1}^{T} S_t \Delta y_t}{\sum_{t=1}^{T-1} (1 - S_{t+1}) S_t}; \qquad AMP_{PT} = \frac{\sum_{t=1}^{T} (1 - S_t) \Delta y_t}{\sum (1 - S_t) S_{t+1}}$$

where *AMP* measures the amplitude of the cycle from peak-to-trough or trough-to-peak.

$$STEEP_{TP} = \frac{AMP_{TP}}{D_{TP}} = \frac{\sum_{t=1}^{T} S_t \Delta y_t}{\sum_{t=1}^{T} S_t}, \qquad STEEP_{PT} = \frac{AMP_{PT}}{D_{PT}} = \frac{\sum_{t=1}^{T} (1 - S_t) \Delta y_t}{\sum_{t=1}^{T} (1 - S_t)}$$

where STEEP measures the steepness of the phases and is calculated by the slope of triangle with the duration as the base amplitude as the height.

$$CM = 0.5\left(AMP_i * D_i\right), \qquad i = TP, PT$$

where *CM* calculates the welfare loss (gain) of a recession (expansion) and is measured by the area of the triangle.

Along the lines of Harding and Pagan (2002a), an index of excess cumulated movements may also be computed; specifically, $E_i = \left(CM_i - ACM_i\right) / ACM_i$ (i = *TP, PT*), where ACM_i is the actual cumulative movement.

2.2 Measures and representation of aggregate economic activity

Choosing the time series that may represent the BC is not as straightforward as non-experts could think, and across history and the literature BC analysis has often been conducted with a variety of alternative approaches. Against a background of some confusion in the definition and measurement of BCs, Harding and Pagan (2005) proposed a set of guidelines about which series should be chosen to analyze the BC (and how can a cycle be detected, which will be the focus of next section).

In BC analysis' earlier days, Burns and Mitchell (1946) and the National Bureau of Economic Research (NBER) considered the real Gross Domestic Product (GDP) as their preferred series for describing the level of economic activity and investigating BCs at quarterly or annual frequencies.

This was the natural choice, once the NBER defined a recession as "*a significant decline in economic activity spread across the economy*"; as a recession affects the economy as a whole and is not being confined to a specific sector, and as real GDP is clearly the best measure of aggregate economic activity, then real GDP should be the basic time series in BC analysis.

However, the NBER has felt the need to have a gauge of global economic activity at a higher frequency, namely at a monthly periodicity. Hence the use of other monthly indicators of global activity, such as real personal income less transfer payments, employment, industrial production and the volume of sales of the manufacturing and wholesale-retail sectors adjusted for price changes. The evolution of both data collection and statistical methods has allowed for the selection of a set of monthly indicators known to be coincident indicators of the global real economic activity. One of these is the Industrial Production Index (IPI), which stands out as an important BC indicator not only for the US but also for the other developed economies – which explains its use in a number of empirical studies of BC synchronization in the literature: Korhonen (2003), Fidrmuc (2001), Savva et. al (2007) and Artis et. al (2004b) are some examples.

Among others, Hann et al. (2007) recognise that GDP and IPI are the two most important variables for BC analysis, at a quarterly and at a monthly frequency, respectively. However, they state that GDP should be preferred to the IPI, in general and in the specific case of the Euro Area, not only because the manufacturing industry represents less than 20% of aggregate output but also because it tends to be more volatile than GDP.

Yet, as argued by Artis *et al.* (2003), the IPI series have the enormous advantage (over GDP) of its monthly periodicity, of being very homogeneous across countries, and usually covering longer samples. In addition, many economies do not really have quarterly national accounts and their quarterly GDP figures are mere conversions of annual GDP to a quarterly periodicity using some acceptable indicators. Clearly, in these cases, a truly monthly IPI should be preferred.

It should nevertheless be noted that a number of analysts and researchers have pointed out the relative fragility of using of a single series like real GDP, which is subject to frequent revisions and available only at a quarterly frequency. For instance, Boehm (1998) advocates the use of a coincident composite index constructed on a comparable international basis, arguing that it would provide more consistent results.

The approach followed in this dissertation is the simple and pragmatic approach of Burns and Mitchell (1946) and Harding and Pagan (2002a): describing a business cycle by means of assessing turning points (a *classical cycle* approach, opposed to the *deviation cycle* approach involving filtering the original series). As argued by Harding and Pagan (2006), the classical view of the BC is the most widespread in media and in policy analysis.

The question remains, however, of how precisely to compute the turning points.The next section will further develop this issue.

2.3 Determining business cycles turning points

As Harding and Pagan (2002a, page 368) state, isolating turning points in the series is the first procedure for detecting a cycle. A turning point is either a local maxima or minima in the chosen series.

In the recent literature there are two essential ways of detecting these turning points: one alternative relies on non parametric methods, such as the algorithm suggested by Bry and Boschan (1971); the other alternative uses parametric models, such as the Markov Switching regime model. Since this is the approach to be pursued in this thesis, a specific chapter will be dedicated to the thorough study of this sort of models.

In spite of their differences, the use of both methodologies in the literature has been conducted under the acceptance of the same aim, which is to mimic official business cycle dating procedures: In the case of the US, the aim is to provide results close enough to those of the NBER, which dates BCs on the basis of a mixture of statistical models, subjective evaluations and judgemental assessments [see Giancarlo and Otranto (2008)].

The Bry and Boschan algorithm, suited for monthly observations, has been recently summarised by Harding and Pagan (2002a) as involving essentially three tasks in the detection of turning points:

1. Determine the peaks and troughs in a series;
2. Ensure that peaks and troughs alternate;
3. Apply censoring rules to the turning points found after steps 1 and 2 in order to satisfy some pre-determined criteria regarding the duration and amplitude of cycles.

The original algorithm, designed for monthly data, defines a local peak occurring at period *t* whenever $\{y_t > y_{t\pm k}\}$, k=1,…, K, where K is set at 5. The third step demands that a phase must last at least 6 months and a complete cycle at least 15 months.

Harding and Pagan (2002a) adapted it to a quarterly frequency, setting K=2, which ensures that y_t is a local maximum relative to two quarters of either side of y_t. This became known as the BBQ algorithm.

More formally, as Harding and Pagan (2002b, page 1683) describe,

Peak at t: $\{(y_{t-2}, y_{t-1}) < y_t > (y_{t+1}, y_{t+2})\}$

Through at t: $\{(y_{t-2}, y_{t-1}) > y_t < (y_{t+1}, y_{t+2})\}$

Which is equivalent to

Peak at t: $\{(\Delta_2 y_t, \Delta y_t) > 0, (\Delta y_{t+1}, \Delta_2 y_{t+2}) < 0\}$

Through at t: $\{(\Delta_2 y_t, \Delta y_t) < 0, (\Delta y_{t+1}, \Delta_2 y_{t+2}) > 0\}$

and $\Delta_2 y_t = y_t - y_{t-2}$.

In order to clarify the distinction between their approach and an alternative known as *growth cycle*, Harding and Pagan (2002a) emphasize that these rules are not meant to locate a cycle in Δy_t; instead, Δy_t is just a means of dating the *classical cycle*, which refers to the (log) level of a variable: the BC characteristics established via the turning points in y_t are determined by the process in Δy_t [Harding and Pagan (2006)].

As a result of these rules, one can define *classical cycle* peaks (troughs) as points at which a series moves from a sequence of positive (negative) growth rates to negative (positive) growth rates [Harding and Pagan (2006)]. [1]

After carrying out the BBQ algorithm including the adequate dating and censuring rules, a binary variable taking the value zero at expansions and one at recessions is computed, and shall be the basis for measuring a cycle's chronology [Harding and Pagan (2005)].

This dichotomic variable may be obtained, alternatively, via a parametric model of the variable representative of real aggregate economic activity. One popular model in BC analysis is the Markov Switching (MS) regime model, which has the advantage of distinguishing between recessions and expansions capturing the asymmetries in the BCs. As the empirical analysis in this dissertation will use this class of models, we defer to chapter 3 its thorough description.

2.4 Synchronization of business cycles

Harding and Pagan (2006, page 59) note that mere visual representations of many specific series may give the impression that they are synchronized in the sense that their turning

[1] Although the BBQ is typically used in dating *classical cycles*, it could also be used in *deviation cycles*, if the original series had been previously filtered to extract non-cyclical fluctuations. See the method in Artis *et. al* (2003), which consists of three main steps: (i) pre-filtering, in order to extract the fluctuations with periodicity larger than the minimum cycle duration; (ii) preliminary identification of turning points using a Markov chain that enforces minimum duration constraints (both for the phase and full cycle) and that turning points alternate and; (iii) final identification of the turning points in the original series.

Their underlying Markov Chain has four states, as expansion and recession states are divided into expansion continuation (EC) and peak (P), and recession continuation (RC) and through (T), respectively. From EC_t the economy can only continue in expansion, $\left(EC_t\right) \to \left(EC_{t+1}\right)$, or achieve a peak; after a peak, only $P_t \to RC_{t+1}$ is a possible transition. These authors also use a version of this algorithm for classical cycles. For a comprehensive overview of both algorithms, see their Appendix A.

points occur at roughly the same period, *i.e.*, they cluster together, thus arguing that there is a need of computing precise synchronization measures.

There are several measures of synchronization available and used in the recent literature. In this section we begin by describing a simple and widely used measure – correlation coefficients – and several refinements to that measure. Then we present several synchronization measures suggested by Harding and Pagan in a number of recent papers and refinements to these measures suggested by other authors – which we classify as indicators in the spirit of Harding and Pagan. Since these will be the basis for the quantitative part of this dissertation, they will be thoroughly described. [2]

2.4.1 Correlation Coefficients

Simple correlation coefficients have been used extensively in the literature to describe the degree of linear association between pairs of business cycles. Because of their simplicity, such coefficients are a handy procedure and offer at least some preliminary grasp on BCs' synchronization: for instance, Artis (2004) computes pairwise contemporaneous correlation coefficients, Artis *et al.* (2004b) calculate pairwise correlation coefficients (as well as contingency indices, which will be presented below), and Agresti and Mojon (2003) analyze the contemporaneous correlation between national BCs with the aggregate euro area cycle.

Evidently, as more recently Kose *et al.* (2008b) have noted, simple correlation coefficients have some disadvantages: calculating bivariate correlations between all variables may prove difficult when there is a large set of data, and resorting to summary measures implies

[2] One recent approach that is being increasingly used in the study of business cycles and their synchronization is the common dynamic factor model. For its origins see, for example, Stock and Watson (1991). Applications to the issue of synchronization include, *inter alia*, Kose et al. (2008b), Diebold and Rudebusch (1996), Kose et al. (2003), Kose et al. (2008a), and Kose et al. (2008b). Interestingly, Diebold and Rudebusch (1996) combine the dynamic factor approach with the MS regime approach.

taking averages that may mask co-movements in some data subset. The most common form of overcoming this inconvenience is specifying a reference country and computing bi-variate correlations with that country.

The surveys of the relevant literature in two recent articles show how correlation coefficients have been extensively used in research on BCs synchronization within the Euro Area. As can be seen in Table 2-1, sourced from de Hann *et al.* (2007), as well as in Table 2-2, sourced from Gouveia and Correia (2007), correlation coefficients appear in a large part of the literature on Euro Area BCs synchronization, both for *classical cycle* definitions and for *deviation cycle* definitions of the BC.

Study	Data used	Mesure of cycle	Convergence measure	Conclusions
Fatás (1997)	Employment growth, EU12, 1966–2002 and subsamples	Employment growth	Correlation with EU12	Post-EMS correlations are generally higher than pre-EMS correlations
Artis and Zhang (1997, 1999)	OECD monthly IP data (15 countries in 1997 paper, 19 in 1999 paper), 1960–1993 (1997) and 1960–1995 (1999)	PAT, HP, linear trend; two subsamples (pre- and post-ERM)	Lead and lag bivariate correlation with Germany and US	Cycles have become more group-specific after ERM, correlations not different across filters after ERM
Angeloni and Dedola (1999)	IP, GDP, stock prices, GDP deflator, CPI, quarterly data 1965–1997, 12 EU countries, US, CAN, JPN	Year-on-year growth rates	Correlations with Germany and US	Significant increase in correlation after 1992
Döpke (1999)	OECD data of 'big 5' euro area countries	HP, linear, segmented trend	Rolling contemporaneous correlations based on five-year moving average of each country with euro area	Correlation between most countries and the euro area increases, but that of BEL falls
Wynne and Koo (2000)	Penn World Tables of GDP, annual data	Baxter–King	Pairwise correlations, using GMM	Null of no correlation between EU founding members rejected, but lower correlation with more recent members
Inklaar and De Haan (2001)	OECD monthly IP data, 1960–1997	HP, two subsamples (pre- and post-ERM)	Bivariate correlation with Germany and US	Mixed outcomes, no replication of results of Artis and Zhang (1999)
Agresti and Mojon (2001)	ECB Euro Area Wide Model (AWM) data of GDP and GDP components for 10 countries	Baxter–King	Contemporaneous and lagged crosscorrelation between each country and the euro area	Each country highly correlated with euro area as whole, with lowest values for periphery
Belo (2001)	GDP, EU15 countries, US, JPN, annual for 1960–1999	HP filter	Correlation, concordance, rank correlation, with euro (11) area	High and increasing association for most euro area countries after ERM
Croux et al. (2001)	GDP, EU15, SWI, NOR, plus personal income for US states, annual for 1962–1997	Spectral decomposition	Dynamic correlations and cohesion (weighted average of dynamic correlations)	Cycles of US states are more similar than cycles of European countries
Harding and Pagan (2001)	ECB AWM data of GDP for euro area, OECD data for US	Harding–Pagan rule on level series and de-trended (linear, HP, PAT) series	Correlation and regression methods on binary series	Relatively low correlation between member countries and euro area
Azevedo (2002)	GDP, EU15 countries, US, JPN, annual from 1960–1999	Co-spectrum of HP filtered series	Dynamic correlation with euro (11) area	High correlation of in-phase cyclical movements
Beine et al. (2003)	Unemployment, FIN, FRA, GER, ITA, NLD, NOR, PRT, SPA, SWI, SWE, UK, quarterly 1975–1996	Recession probabilities from a Markov switching VAR model	Several indicators based on recession probabilities similar to concordance indices	More synchronization amongst EMU members, compared to European periphery
Koopman and Azevedo (2003)	GDP, FRA, GER, ITA, NLD, UK, US, euro (12), quarterly 1970–2001	Christiano–Fitzgerald filter	Correlations and phase shifts with euro (12) area	Increases in correlation and synchronization within euro zone
Sopraseuth (2003)	Quarterly data GDP, consumption, investment, exports 1971.3–1979.2 and 1987.1–1998.4, 17 countries	HP filter	Correlations of filtered data	Membership in EMS did not result in increased correlations, but during EMS period countries are more synchronized with German than with the US cycle
Garnier (2003)	Monthly IP for 18 countries, 1962–2001; before and after EMS	Analysis is based on various characteristics (including concordance index) of classical cycle determined by BB procedure	Comparison with cycles of Germany and US	Core group of euro countries (which does not include Belgium) shows increased similarity with German cycle

Massmann and Mitchell (2004)	OECD monthly IP data, 1960.1–2000.8	Various methods	Pairwise correlation coefficients using a method of moments estimator; the entire distribution of all correlation coefficients is focused upon, using rolling windows	Euro area has 'switched' between periods of convergence and divergence many times in the last 40 years; in more recent period evidence of increasing synchronization
Darvas and Szapáry (2007)	OECD's Quarterly National Accounts GDP and components for 10 euro area countries; quarterly data between 1983 and 2002 grouped in four non-overlapping five-year periods	HP and BP filter	Cycle correlation with euro area, leads/lags, volatility, persistence of the cycle and a measure of impulse–response	Rather strong co-movement with the euro area for most EMU members; more synchronization over time according to all the correlation measures calculated, particularly since 1993
Artis et al. (2004a)	Industrial production, AUT, BEL, FRA, GER, ITA, NLD, SPA, 1970–1996, monthly	Probability of being in a recession based on Markov switching models	Correlation, contingency coefficient, variance decomposition	Considerable commonality but also important domestic (non-EU) component
Altavilla (2004)	GDP of BEL, FRA, GER, ITA, SPA, UK, US 1980–2002, quarterly	Classical and deviation cycles based on BB and Harding–Pagan procedures; trend for deviation cycle determined using HP and BP filters; for classical cycle Markov switching model is used	Characteristics of cycles (like duration, amplitude, steepness) and (correlation of) concordance measure compared with euro area	Deviation cycles of EMU countries are reasonably aligned, but classical cycles diverge more; after 1991 EMU countries became more synchronized
Hughes Hallett and Richter (2004, 2006)	GDP of US, UK, Eurozone and Germany, quarterly for 1980–2003	Spectral decomposition	Time-varying coherence	Coherence between GER and Eurozone has decreased, while coherence between UK and Eurozone is unstable, but stronger than link with US
Camacho et al. (2006)	Monthly IP for most current and future EU countries and CAN, JPN, NOR and US, 1965–2003	Comprehensive measure that consists of average of three measures of synchronization	Pairwise correlation of comprehensive measure	Relatively high linkages across euro countries, but these are prior to the establishment of the monetary union

Table 2-1: Studies on Business Cycle Synchronization in the Euro Area A

AUT, Austria; AUS, Australia; BEL, Belgium; CAN, Canada; FIN, Finland; FRA, France; GER, Germany; GRE, Greece; IRE, Ireland; ITA, Italy; JPN, Japan; NLD, Netherlands; NOR, Norway; PRT, Portugal; SPA, Spain; SWE, Sweden; SWI, Switzerland; UK, United Kingdom; US, United States; euro (12), euro area; euro (11), euro area, excluding Greece; EU15, European Union as of 1995
Source: De Haan *et al.* (2008, pp. 242-248)

Authors	Data	Measure of cycle	Measure of synchronization	Conclusions
Artis and Zhang (1997, 1999)	OECD data on monthly industrial production, 1961:1-1993:12 (1997); 1961:1-1995:10 (1999); All euro area countries except AUS, FIN and LUX, plus six other countries.	Deviation cycles extracted via 3 methods: PAT, HP filter and linear trending.	Two sub-samples (pre-ERM period and ERM period); Contemporaneous and maximum correlation coefficients with Germany (and with the USA).	Overall, the synchronicity and linkage between ERM economies and Germany has grown strongly between the two sub-periods (whilst the linkages with the USA cycle have diminished). For Portugal and Spain (who joined the ERM in 1989 and 1992, respectively) the degree of synchronisation with the German cycle in the ERM period is less than that of any other ERM country. Results appear robust across filtering method.
Dickerson et al. (1998)	OECD data of annual real GDP indices, 1960-1993; All euro area countries plus 11 other countries.	Deviation cycles extracted via HP filter.	Three sub-periods (1960s, 1970s and 1980/90s); Pairwise correlations coefficients (to analyse the timing of cycles); MADs (to measure the amplitudes of cycles)	The authors find no evidence that business cycles in the EU12 have become more synchronised after the formation of the ERM. There is a clear core-periphery distinction within the EU in both the time and magnitude of cycles. Evidence of strong comovements among a core group (AUS, BEL, FRA and DEU), not shared by all other EU countries.
Wynne and Koo (2000)	OECD data of total employment (1960-1996), and annual total output (1963-1992); All euro area countries plus three EU countries.	Deviation cycles extracted via BK band pass filter.	Pairwise correlations coefficients and standard deviation using GMM.	In the EU founding members (BEL, FRA, DEU, ITA, LUX and NLD) the cycles show a higher degree of synchronisation than in any of the other countries that joined the EU in a later stage. The cyclical dispersion among euro area cycles appears to be decreasing by decade.
Inklaar and de Haan (2001)	OECD data of industrial production, 1961:1-1997:12; All euro area countries except PRT, plus seven other countries.	Deviation cycles extracted via 3 methods: PAT, HP filter and linear trending.	Four sub-periods (1960-71; 1971-79; 1979-87; 1987-97); Contemporaneous correlation coefficient with German cycle.	Overall, no evidence that business cycles in the ERM countries have become more synchronised after the formation of the ERM. Most ERM countries show an increase in correlation with Germany from 1960-71 to 1971-79, but a decrease from 1971-1979 to the 1979-87 period.
Agresti and Mojon (2003)	ECB AWM data of GDP, 1970:1-2000:4; All euro area countries except LUX and IRL, plus US.	Deviation cycles extracted via BK band pass filter.	Contemporaneous correlation of each national business cycle with the aggregate euro area cycle.	The contemporaneous correlations are relatively high for most of the countries (between 0.7 and 0.92). The exceptions are for the countries in periphery such as Greece, Portugal or Finland (where the correlation drops to around 0.4).
Artis et al. (2004a)	OECD data of industrial production, 1961:1-1996:12; All euro area countries except GRC, IRL, FIN and LUX, plus UK	Deviation cycles proxied by smoothed probabilities of recession regimes estimated via Markov switching models.	Pairwise correlation coefficients and contingency indices.	Overall, relatively high correlation and contingency values among euro area countries.
Artis (2004)	IMF data of quarterly real GDP indices, 1970:1-2001:4 (NLD and PRT: 1997; BEL:1980, IRL:1997) All euro area countries except Luxemburg, plus other countries	Deviation cycles extracted via a band pass filter based on combining two HP low-pass filters.	Three sub-periods (1970-79; 1980-92; 1993-2001); Pairwise contemporaneous correlation coefficients.	Overall, evidence of high correlation of all euro area cycles with euro area aggregate cycle and indications of increasing synchronisation during 90s.
Massmann and Mitchell (2004)	OECD data of industrial production, 1961:1-2001:8; All euro area countries.	Deviation cycles extracted alternatively via three parametric methods (BN, UC, TIM) and four nonparametric methods (MA, HP, BK, PAT); Classical cycles using one measure proposed by Harding & Pagan.	Pairwise contemporaneous correlations and standard deviations using GMM; Rolling correlation coefficient.	Although empirical inference about individual euro area business cycles is found to be sensitive to the measure of the business cycle, the measure of convergence exhibits common features across the alternative measures of cycle. Euro area has been characterised by periods of convergence, and periods of divergence. Evidence suggest that euro area has entered a period of convergence after the period of diverge in the early 90s. Some evidence that over the past 20 years correlations on average tended to increase.

Altavilla (2004)	OECD data of real GDP, 1980:1-2002:4. Five euro area countries(BEL, DEU, ESP, FRA, ITA), euro area, the UK and US	Deviation cycles extracted via HP filter and BK band pass filter; Classical cycles based on MS-AR	Two sub-periods: 1980-1991; 1992-2002. Cross-correlation coefficients and concordance indices.	Overall, the business cycles were reasonably similar across European countries in both their duration and amplitude. During the 1992-2002 period the euro area cycles become more synchronised, which suggest that adhesion to new currency area is likely to lead to stronger synchronisation of EMU members´ business cycles.
Pérez et al. (2007)	OECD and IMF data of GDP, 1960:1-2002:1; All euro area countries except GRC, IRL, LUX and PRT, plus five other countries.	Deviation cycles extracted via HP filter and BK band pass filter; Growth rates.	Rolling contemporary correlations and maximum positive correlation with Germany (and with USA); correlations over sub-periods (1960-1979, 1980-1990, 1991-2002 and 1993-2002).	Overall, the euro area countries cycles (FRA, ITA, ESP and NLD) become more synchronised with the German cycle, particularly since the 90s.

Table 2-2: Studies on Business Cycle Synchronization in the Euro Area B

PAT = phase-average-trend; HP = Hodrick and Prescott; BK = Baxter King; MAD = mean absolute deviation; GMM = generalized methods of moments; AWM = Euro Area Wide model; BN = Beveridge-Nelson decomposition; UC = Unobserved components models; TIM = Linear regression models; MA = moving average; MS-AR = Markov-switching autoregressive models
Source: Gouveia and Correia (2007, pages 20-21)

Two lessons of interest for our research may be drawn from these tables.

First, there is a marked diversity of results apparent in those tables. These differences may be explained by the diversity of data sets, of methods for identifying business cycles, and of methods for assessing their convergence.

Second, besides or in alternative to correlation coefficients, other measures of synchronization have been emerging in the literature. Most of these measures have been suggested by Harding and Pagan or by other researchers building on their work. Hence, we classify these as synchronization indicators in the spirit of Harding and Pagan. As these alternative measures are crucial to our own quantitative investigation in this dissertation, we defer to an autonomous section (2.4.2) the extensive presentation and discussion of such indicators.[3]

For the moment, we concentrate a bit further on lesson one.

[3] In the tables there are examples of other sophisticated measures of correlation, such as the dynamic correlation measure of Croux et al. (2001) or the phase-adjusted correlations of Koopman and Azevedo (2003), which will not be developed in this dissertation, as we do not consider them measures in the spirit of Harding and Pagan.

The lack of consensus is quite evident in the contrast between the results of Artis and Zhang (1997) and Inklaar and de Hann (2001). While the former find that since 1979 there was evidence of increased integration for the member countries of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS), the latter, using the same data, argue that from 1971 to 1979 the cycles of the euro area countries are more correlated with the German business cycle than in the period 1979-1987.

Massmann and Mitchel (2004) also look at the correlations of cyclical indicators, using monthly industrial production data spanning through 40 years, and eight different measures of the business cycle. They conclude that there have been both periods of convergence (with an increase in average correlation and a decrease in variance), and periods of cyclical divergence. They detect a positive trend in the correlations until the mid 1970's (when they reached peaks of 0.8 for most measures of the business cycle), while in the mid 1980's the correlations become statistically insignificant -- a result that seems to validate Inklaar and de Hann's (2001). After this slump, the correlations begin rising to as much as 0.6-0.8 until the early 1990's, time at which they drop dramatically. Massmann and Mitchell (2004) show that for the most recent period the correlations between the then 12 EMU member-states' cycles were statistically positive.

Correlation coefficients have also been extensively used in research on the synchronization of the BCs of CEECs and the Euro Area. As the review in Fidrmuc and Korhonen (2003a) shows – which is summarized in Table 2-3 – studies using correlation coefficients have overall found that the degree of synchronization of the most advanced acceding countries with the Euro Area is similar to the one of the most peripheral countries of the Euro Area.

Study, year of publication	Methodology and variables	Acceding countries	Comparison country/area	Period analyzed
Boone and Maurel (1998)	Correlation of detrended industrial production and unemployment	BLG, CZE, HU, PL, ROM, SL, SI	EU and DE	M1:1990-M11:1997
Boone and Maurel (1999)	Share of changes in unemployment rate explained by European or German shocks and correlation of their impulse response functions	CZE, HU, PL, SL	EU and DE	M1:1991-M12:1997
Frenkel et al. (1999)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, LV, LT, PL, ROM, SL, SI	FRA and DE	Q1:1992-Q2:1998
Horvath (2002)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, LV, LT, PL, SL, SI	FRA, DE, IT and UK	Q1:1993-Q4:2000
Fidrmuc (2001)	Correlation of detrended industrial production (endogeneity)	CZE, HU, PL, SL, SI	DE	M1:1991/3-M12:1999
Fidrmuc and Korhonen (2003b)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CRO, CZE, EST, HU, LV, LT, PL, ROM, SL, SI	Euro area and euro area countries	Q2:1993-Q4:2000
Frenkel and Nickell (2002)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, PL, SL, SI	FRA, DE, and IT	Q1:1993-Q4:2001
Babetski et al. (2002)	SVAR (time-varying correlation coefficients of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, LV, LT, PL, ROM, SL, SI	EU and DE	Q1:1990-Q4:2000
Maurel (2002)	Correlation of detrended industrial production(endogeneity)	EST, CZE, HU, PL, ROM	EU countries	M1:1993-M12:1997
Korhonen (2003)	Correlation of VAR impulse functions, industrial production	CZE, EST, HU, LV, LT, PL, ROM, SL, SI	Euro area	M1:1992/3/5-M12:2000

Table 2-3: Studies on correlation of business cycles between EU acceding countries and the euro area
BLG = Bulgaria, CRO = Croatia, CZE = the Czech Republic, DE = Germany, EST = Estonia, FRA = France, HU = Hungary, IT = Italy, LV = Latvia, LT = Lithuania, PL = Poland, ROM = Romania, SL = Slovakia, SI = Slovenia, UK = United Kingdom; SVAR = Structural vector autoregressive model, VAR = Vector autoregressive model
Source: Fidrmuc and Korhonen (2003a, pp. 11)

These and other results will be studied more thoroughly in later chapters. We now turn to the second lesson offered by Table 2-1 and Table 2-2, and focus on alternative measures of BCs synchronization that have been suggested by Harding and Pagan or by other researchers in their spirit – which will be the focus of our quantitative work in chapter 4.

2.4.2 Harding and Pagan's view on synchronization

The basis for this section is mainly Harding and Pagan's (2006) statistical methods for detecting synchronization of BCs. Whereas these methods can be applied either to *classical* *cycles*, *growth cycles* or *deviation cycles* the authors focus specifically on *classical cycles*, which will also be the focus of this dissertation.

As mentioned in section 2.3, one could use two essential different ways to determine a random variable S_t that takes the value zero at expansions and one at recessions. As should be clear from the discussion in that section, the properties of S_t depend on the rule that is used to identify a cycle, as well as on the nature of the series Δy_t that is subject to the dating rules [Harding and Pagan (2006)].

We now focus on the main measures and, subsequently, statistical tests, suggested by Harding and Pagan and by other researchers that have presented indicators in their spirit or refining their measures.

A first measure for assessing BCs synchronization is the *concordance index*. This index simply states the fraction of time in which the cycles are in the same phase

$$\hat{I} = \frac{1}{T}\left\{\sum_{t=1}^{T} S_{xt}S_{yt} + \sum_{t=1}^{T}(1-S_{xt})(1-S_{yt})\right\} \qquad \textbf{Equation 2-1}$$

where T is the sample size. After some mathematical derivations one arrives at the following equivalent formula

$$\hat{I} = 1 + 2\hat{\rho}_S\left(\hat{\mu}_{S_x}\left(1-\hat{\mu}_{S_x}\right)\right)^{1/2}\left(\hat{\mu}_{S_y}\left(1-\hat{\mu}_{S_y}\right)\right)^{1/2} + 2\hat{\mu}_{S_x}\hat{\mu}_{S_y} - \hat{\mu}_{S_x} - \hat{\mu}_{S_y}$$

where $\hat{\rho}_S$ is the estimated correlation coefficient between S_{xt} and S_{yt}. When $S_{xt} = S_{yt}$ the index will assume the value unity and zero when $S_{xt} = (1 - S_{yt})$. As a result, when either of these holds, $\hat{\sigma}_{S_x}\hat{\sigma}_{S_y} = \hat{\sigma}^2_{S_x}$, and so $\hat{\rho}_S = 1$ corresponds to an index of one and $\hat{\rho}_S = -1$ to an index of zero. It should also be noted that the index is monotonic in ρ_S.

There are some examples of the use of such index in literature relevant for our dissertation. One example is Avouyi-Dovi *et al.* (2006), who applied this methodology to industrial production indexes of Poland, Hungary and the Czech Republic and assessed the concordance of their cycle with the Euro Area's. The results were 0.72093 for Euro area-Poland, 0.82946 for Euro area-Hungary and 0.55039 for Euro area-Czech Republic.

An equivalent *concordance* index may be applied to *deviation cycles*, as in Mink, Jacobs and de Haan (2007). Denoting the reference output gap for the region *r* as $g_r(t)$, the authors calculate synchronization in period *t* between the business cycle of the *n* countries in the sample and this reference as

$$\varphi(t) = \frac{1}{n}\sum_{i=1}^{n}\frac{g_i(t)g_r(t)}{|g_i(t)g_r(t)|}$$

where $g_i(t)$ represents the output gap for country *i*. When the results of $\varphi(t)$ are scaled down to the interval $[0,1]$, this index indicates the percentage of countries whose output gap has the same sign as the one in the reference cycle.

Synchronization between an individual country *i* and the reference cycle may be expressed as

$$\varphi_{ir(t)} = \frac{g_i(t)g_r(t)}{|g_i(t)g_r(t)|}$$

which represents the fraction of time in which the output gap of country *i* has the same sign as the output gap in the reference cycle. $\varphi_{ir}(t)$ is invariant to the amplitude of the business cycle.

Artis *et. al* (2003) come up with yet another related measure of synchronization: the *diffusion* index. This index measures the share of countries that are in a recession if the

Euro Area is itself in recession. As de Hann *et al.* (2007) put it, whereas the *concordance* index summarizes bilateral comovement of two series, the *diffusion* index enables an analysis of the comovement within an aggregate Area.

A second coefficient that has also been used in recent literature and is close to a *concordance* index is *Pearson's contingency coefficient*. For example, Garnier (2003) and Artis et al (2004a) have used it in parallel to the *concordance* index.

Pearson's corrected contingency coefficient – which will be used in our quantitative assessment in chapter 4 – is computed as follows: after having obtained the binary series $S_{i,t}$ (with value one at recessions and zero at expansions), a contingency table of expansions and recessions for each pair of countries (*i, j*) is calculated:

		Country *j*		
		Expansion	Recession	Subtotal
Country *i*	Expansion	n_{00}	n_{01}	$n_{0.}$
	Recession	n_{10}	n_{11}	$n_{1.}$
	Subtotal	$n_{.0}$	$n_{.1}$	N

Pearson's Contingency Coefficient is then defined as:

$$CC = \sqrt{\frac{\hat{\chi}^2}{N + \hat{\chi}^2}} \quad \text{where } \hat{\chi}^2 = \sum_{i=0}^{1} \sum_{j=0}^{1} \frac{\left(n_{ij} - \frac{n_{i.} n_{.j}}{N}\right)^2}{\frac{n_{i.} n_{.j}}{N}}$$

Given the fact that its maximum attainable value (for a 2x2 table) is $\sqrt{0.5}$, the coefficient is corrected so that its value lies between 0 and 100, as follows:

$$CC_{corr} = \frac{CC}{\sqrt{0.5}} 100$$

If the two binary series are independent, then CC and CC_{corr} take the value zero, as $n_{ij} = n_{i.}n_{.j}$; if they are completely dependent, $n_{ij} = n_{i.}n_{i.}$ (i=0,1), so that CC= $\sqrt{0.5}$ and CC_{corr} equals one.

Independence means that there is no contemporaneous relationship between the two business cycle regimes; complete dependence means that both countries share the same regime for every time period.

We now turn to statistical tests of synchronization that have been suggested by Harding and Pagan, closely following Harding and Pagan (2006).

Harding and Pagan (2006) refer to S_t as the *specific cycle* of a variable and they begin by focusing on the unconditional densities of S_{xt} and S_{yt}. If two random variables S_{xt} and S_{yt} are identical one can speak of *strong perfect positive synchronization* (SPSS). Given the fact that the variables are binary, necessary and sufficient conditions for this form of synchronization are

a) $\Pr(S_{yt} = 1, S_{xt} = 0) = 0$
b) $\Pr(S_{yt} = 0, S_{xt} = 1) = 0$

On the other hand, if S_{xt} and S_{yt} are independent then the cycles are *strongly non-synchronized* (SNS), so that the joint probability function for S_{xt} and S_{yt} factorizes into the product of marginal probability functions.

As S_{xt} and S_{yt} are binary variables, the probabilities in the preceding equations can be transformed to represent expectations:

SPSS (a): $E(S_{yt}(1 - S_{xt})) = E(S_{yt}) - E(S_{xt}S_{yt}) = 0$ **Equation 2-2**
SPSS (b): $E(S_{xt}(1 - S_{yt})) = E(S_{xt}) - E(S_{xt}S_{yt}) = 0$ **Equation 2-3**
SNS: $E(S_{xt}S_{yt}) - E(S_{xt})E(S_{yt}) = 0$ **Equation 2-4**

Subtracting SPSS (b): $E(S_{xt}(1-S_{yt})) = E(S_{xt}) - E(S_{xt}S_{yt}) = 0$ Equation 2-3 to SPSS (a): $E(S_{yt}(1-S_{xt})) = E(S_{yt}) - E(S_{xt}S_{yt}) = 0$ Equation 2-2, one thus obtains

SPPS (i): $E(S_{yt}) - E(S_{xt}) = 0$ **Equation 2-5**
SPSS (ii): $E(S_{xt}) - E(S_{xt}S_{yt}) = 0$ **Equation 2-6**

While SNS: $E(S_{xt}S_{yt}) - E(S_{xt})E(S_{yt}) = 0$ Equation 2-4 states that the unconditional densities of S_{xt} and S_{yt} are identical, SPSS (ii): $E(S_{xt}) - E(S_{xt}S_{yt}) = 0$

Equation 2-6 implies that

$\mu_{S_x} - \sigma_{S_x}\sigma_{S\,y}\rho_S + \mu_{S_x}\mu_{S_y} = 0$ **Equation 2-7**

where $\mu_{S_x} = E(S_{xt}), \mu_{S_y} = E(S_{yt})$ and ρ_S is the correlation coefficient between S_{xt} and S_{yt}. When SPPS (i): $E(S_{yt}) - E(S_{xt}) = 0$ Equation 2-5 holds, $E(S_{yt}) = E(S_{xt}) = \mu_S$ and $\sigma^2_{S_x} = E(S_{xt})(1 - E(S_{xt})) = \sigma^2_{S_y}$ so that Equation 2-7 becomes

$(1-\rho_S)\mu_S(1-\mu_S) = 0$
which implies that $\rho_S = 1$.

Thus, a test for perfect synchronization may be a test of the null hypothesis that $\mu_{S_x} = \mu_{S_y}$ and $\rho_S = 1$. On the other hand, when testing for SNS we have $\sigma_{S_x}\sigma_{S\,y}\rho_S = 0$ which implies the null hypothesis that $\rho_S = 0$.

Given these derivations, it is now clear the basis for the statistics that allow testing for synchronization, which are as follows:

SPPS (i): $\hat{\mu}_{S_x} - \hat{\mu}_{S_y}$
SPPS (ii): $\hat{\rho}_S - 1$

SNS: $\hat{\rho}_S$

Although the original series might not have a strong serial correlation, once they are converted in the binary form, both S_{xt} and S_{yt} become serially correlated. In fact, there may exist significant differences between synchronization tests that are corrected from heteroskedasticity and autocorrelation and those that are not. As such, Harding and Pagan (2006, page 69) suggest using GMM in order to allow for inferences that are robust to any heteroskedasticity and/or serial correlation.

Similarly, the asymptotic test performed by Artis, Marcellino and Proietti (2003) is based on a standardised *concordance* index, which is obtained by dividing a mean corrected *concordance* index I_{ij}^* (defined below) by a consistent estimate of its standard error under the null of independence.

Defining $\hat{\mu}_i = \frac{\sum_{t=1}^{T} S_{it}}{T}$ as the estimated probability of being in state 1, the mean corrected *concordance* index will be: $I_{ij}^* = 2\frac{1}{T}\sum_{t=1}^{T}(S_{it} - \hat{\mu}_i)(S_{jt} - \hat{\mu}_j)$

As under the null:

$$Var(I_{ij}) = \frac{4}{T^2}\mathrm{E}\left[\sum_{t=1}^{T}(S_{it} - \mathrm{E}(S_{it}))(S_{jt} - \mathrm{E}(S_{jt}))\right]^2 = \frac{4}{T}\left[\gamma_i(0)\gamma_j(0) + 2\sum_{\tau=1}^{T-1}\frac{T-\tau}{T}\gamma_i(\tau)\gamma_j(\tau)\right]$$

Where $\gamma_i(0) = \mathrm{E}[(S_{it} - \mathrm{E}(S_{it}))(S_{i,t-\tau} - \mathrm{E}(S_{it}))]$

Then it follows that

$$\sqrt{T}I_{ij}^* \to N(0, 4\sigma^2), \quad \sigma^2 = \gamma_i(0)\gamma_j(0) + 2\sum_{\tau=1}^{\infty}\gamma_i(\tau)\gamma_j(\tau)$$

and a consistent estimator of σ^2 is given by $\hat{\sigma}^2 = \hat{\gamma}_i(0)\hat{\gamma}_j(0) + 2\sum_{\tau=1}^{l}\left(1 - \frac{\tau}{T}\right)\hat{\gamma}_i(\tau)\hat{\gamma}_j(\tau)$

where *l* is an appropriate truncation parameter.

In practice, this is equivalent to regressing by OLS S_{it} on S_{jt} and evaluating the t-value for the $\hat{\beta}$ coefficient with a heteroskedasticity and auto-correlation consistent variance-co-variance matrix:

$$S_{it} = \alpha + \beta . S_{jt} + \varepsilon_t$$

Which can be seen from the formula of the estimator for β:

$$\hat{\beta} = \frac{COV(S_{it}, S_{jt})}{VAR(S_{jt})} = \frac{\dfrac{\sum_{t=1}^{T}(S_{it} - \hat{\mu}_i)(S_{jt} - \hat{\mu}_j)}{T}}{VAR(S_{jt})} = \frac{I_{ij}^*}{2VAR(S_{jt})}$$

provided that a Newey-West consistent covariance matrix of $\hat{\beta}$ is used.

An example of the use of standardized *concordance* indexes in literature relevant for our dissertation is Artis *et. al* (2004b), who have used industrial production data for the Czech Republic, Slovak Republic, Poland, Hungary, Slovenia, Estonia, Latvia, Lithuania, Germany, Italy, Austria and the Euro area. Their results are summarized in the following table:

	CZE	SVK	POL	HUN	SVN	EST	LVA	LIT	D	A	I	EURO
CZE	-	1.53	0.4	-0.39	**3.24**	**3.26**	1.99	1.38	1.94	-0.92	1.18	1.67
SVK	1.53	-	1.09	0.41	**2.36**	**2.44**	0.74	1.76	-0.54	-0.7	1.13	0.62
POL	0.4	1.09	-	1.79	0.6	0	-0.55	-0.4	0.9	**2.62**	**2.96**	**3.26**
HUN	-0.39	0.41	1.79	-	0.81	0.59	-1.58	-0.85	**2.96**	**2.91**	0.75	2.03
SVN	**3.24**	**2.36**	0.6	0.81	-	**3.58**	0.72	1.39	0.96	-0.78	-0.18	0.22
EST	**3.26**	**2.44**	0	0.59	**3.58**	-	1.55	1.47	1.08	-1.03	-0.52	0.09
LVA	1.99	0.74	-0.55	-1.58	0.72	1.55	-	1.93	-0.01	-1.32	1.58	0.45
LIT	1.38	1.76	-0.4	-0.85	1.39	1.47	1.93	-	-0.88	-1.04	0.01	0.17
D	1.94	-0.54	0.9	**2.96**	0.96	1.08	-0.01	-0.88	-	1.99	1.18	**2.76**
A	-0.92	-0.7	**2.62**	**2.91**	-0.78	-1.03	-1.32	-1.04	1.99	-	1.7	**3.15**
I	1.18	1.13	**2.96**	0.75	-0.18	-0.52	1.58	0.01	1.18	1.7	-	**3.18**
EURO	1.67	0.62	**3.26**	2.03	0.22	0.09	0.45	0.17	**2.76**	**3.15**	**3.18**	-

Table 2-4: Standardized *Concordance* Index

Values greater than 2.33 (99^{th} percentile of a standard normal variate) in bold; computed on available data points from 1993 to 2002

CZE = the Czech Republic; SVK = Slovakia, POL = Poland; HUN = Hungary; SVN = Slovenia, EST = Estonia, LVA = Latvia, LIT = Lithuania; D = Germany, A = Austria , I = Italy

Source: Artis *et al.* (2004b, pp. 32)

These results should be interpreted as a *t*-statistic for the null hypothesis of independence of the cycles, as should be clear from the discussion above.

At a 1% significance level, Poland and Hungary have significant concordance with some countries of the Euro Area and with the Euro Area itself. For a higher but acceptable level of significance, it is also possible to reject the null hypothesis of independence between the Czech Republic's business cycle and that of the Euro Area. For the remaining accession countries, the null cannot be rejected.

3 Markov Switching regime models: a review of their use in business cycle studies

As mentioned in chapter 2 that there were two alternatives to determine business cycles (BCs) turning points (and thus computing the binary variable S_{xt}): a non parametric approach, of which the Bry and Boschan algorithm is the most popular example, and a parametric approach, which includes nonlinear models such as the Markov Switching (MS) regime model.

This chapter explores the parametric approach and, more specifically, the MS regimes model, which will be used in our quantitative study in chapter 4. Section 3.1 presents a simple introduction to MS regime models, including a brief summary of the motivation that led to its genesis. Section 3.2 presents the particular case of the baseline model that is typically used in BC studies, and section 3.3 explores some refinements of the original model.

3.1 Introduction

Markov Switching (MS) regime models are time-series models in which a variable of interest is supposed to change between different regimes according to a Markov chain. Hence, MS regime models belong to the class of nonlinear time series models, as they assume that the variable of interest evolves shifting discretely between two or more stationary processes, rather according to a unique linear one.

As their estimation provides estimates of the characteristics of each regime and the timing of regime changes, they have been considered quite useful to define business cycle chronologies: in that case, regime changes identify turning points, which may subsequently be used to study BCs issues such as synchronization [Smith and Summers (2005)].

MS regimes models have been popular in BCs analysis since the seminal paper by Hamilton (1989). The basic motivation at the origin of these models was the observation that, as Hamilton (1989) reviewed, Neftci (1984), Stock (1987), Diebold and Rudebusch (1990), Simpson *et al.* (2001), and Sichel (1993), among others, documented a recurrent asymmetry between expansions and contractions that implies some limitation for linear models to account for BCs. Evidence of such an asymmetry abounds in yet more recent literature: for example, Kontolemis (1997) found it in G7 countries' industrial production. As Bengoechea and Quirós (2004) put it, a nonlinear phenomenon such as a BC turning point must be detected with a nonlinear technique. The advantage of the MS regimes model, in the words of Hamilton (1989) is that it imposes no *a priori* definition of business cycle, considering that "the turning point is a structural event that is inherent in the data-generating process", but encompassing non-linear behaviours such as those that seem to exist in most cyclical data.

Actually, references to the asymmetry of the BC exist in the early literature of macroeconomics. For example, Keynes (1936) noted that "the substitution of a downward for an upward tendency often takes place suddenly and violently, whereas there is, as a rule, no such sharp turning point when an upward is substituted for a downward tendency". Or, as Friedman (1964) stated, "the amplitude of a contraction is strongly correlated with the succeeding expansion although the amplitude of an expansion is uncorrelated with the amplitude of the succeeding contraction".

These asymmetries in depth and duration of output growth phases are well captured by MS regimes models. Hence their ability to, in general, fit the data better than linear models of output growth [Smith and Summers (2005)].

3.2 A particular case of the baseline MS-regime model

In modern economies, all indicators of real economic activity present upward trends. Yet, these trends are not monotonically increasing, but rather exhibit upturns and downturns that characterize the business cycle phases [Camacho and Quirós (2006)].

In such a context, the expected value of the rate of growth of the series (representative of real economic activity) differs from one period to another. Denoting $\Delta y_t = 100 * \ln(Y_t / Y_{t-1})$, supposing $y_t \sim I(1)$, and following the demonstration by Bengoechea and Quirós (2004, page 9) it is clear that

$E(\Delta y_t) = \mu_2 > 0$ if the economy is in an expansion and

$E(\Delta y_t) = \mu_1 < 0$ if the economy is in a recession

Theoretically, it is the state of the economy that determines these expected values, which in turn may be rewritten as

$$\Delta y_t = \mu_{s_t} + u_t$$

The observed time series Δy_t will depend upon the unobserved regime variable $s_t \in \{1,2\}$ that represents the probability of the economy being in some state.

The term u_t follows, by assumption, an AR (p) process, thus modelling the autocorrelation in the dynamics of the series:

$$u_t = \sum_{i=1}^{p} A_i u_{t-i} + \varepsilon_t \qquad , \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

Combining both equations we get

$$\Delta y_t = \mu_{s_t} + \sum_{i=1}^{p} A_i \left(\Delta y_{t-i} - \mu_{s_{t-i}}\right) + \varepsilon_t$$

or

$$\Delta y_t - \mu_{s_t} = A(L)\left(\Delta y_{t-1} - \mu_{s_{t-1}}\right) + \varepsilon_t$$

Hamilton's (1989) considered that the variance of the error term was not regime dependent. However, in later refinements of this model, this assumption has been relaxed (see section 3.3.5 for a presentation of a generic MS regime model).

The specification of the MS-regimes model proceeds with imposition of the assumption that changes in regime are generated by a stochastic process which is an irreducible ergodic[1] two-state Markov chain defined by the following specification

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i), \qquad \sum_{i=1}^{2} p_{ij} = 1, \qquad \forall i, j = 1,2$$ **Equation 3-1**

This specification may be expressed as a 2x2 transition matrix

$$P = \begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}$$ **Equation 3-2**

In practical usage of the MS-regimes models one typically is interested in estimating the model with some available time series. The estimation of the parameters of the MS regime model is generally done via Maximum Likelihood, using the Expectation-Maximization algorithm. This consists of a recursive procedure iterating between an Expectation step, which runs the regime inference given the parameters of the previous iteration, and a Maximization step, which uses the resulting smoothed probabilities to perform the parameter estimation [Krolzig (1997b)].

The regimes are then reconstructed by inferring the probabilities of the unobserved regimes, conditional on the available information set [Krolzig (2001a)], in such a way that they are endogenously estimated. Conditional probabilities of expansionary and contractionary growth phases can be constructed post-estimation to suggest turning points [Goodwin (1993)].

Hamilton (1989) classified a certain period as a recession when the probability of being in a recession was higher than the probability of being in an expansion, and this rule has

[1] A Markov chain is said to be irreducible if all states are communicable; a state *j* can be i) recurrent if it is not transient, ii) transient if there is a state *k* that can be reached from *j*, but once in *k*, *j* cannot be reached, iii) a-periodic, iv) ergodic if it is recurrent, a-periodic and communicable.

thereafter been used in the literature. The probability considered may be the filtered regime probabilities or the smoothed regime probabilities, but typically is the latter. While the former make an optimal inference on the state variable at time t using just the information up until that period, $\Pr(s_t = m \mid Y_t)$, the latter uses the full sample information $\Pr(s_t = m \mid Y_T)$, with m being the regime [Krolzig (2001a)].

The classification of regimes and the inherent dating of the business cycle consists in assigning every observation y_t to the regime $s_t \in \{1,...,M\}$ with the highest smoothed probability such that

$$\hat{s}_t = \arg\max_{1,...,M} \Pr(s_t \mid Y_T)$$

When there are only two regimes, $s_t \in \{1,2\}$, this classification rule can be simplified in the following manner: the observation will be assigned to the first regime if $\Pr(s_t = 1 \mid Y_T) > 0.5$ and to the second if $\Pr(s_t = 1 \mid Y_T) < 0.5$.

The transitions of the regime variable are then used to date the turning points of the business cycles. We can then get a binary series of the sort of S_t, seen in the previous chapter.

Applying this model to quarterly post-war data of the American economy, Hamilton (1989) estimated the growth of real GNP to be 1.16% during expansions, which lasted on average 10.5 quarters, and -0.36% during recessions, which in turn lasted on average 4.1 quarters. Moreover, the estimated boom and recession periods roughly mimic the NBER business cycle phases [see also Phillips (1991)].

After Hamilton's seminal paper, the MS-regime model has been applied extensively in the literature, with results overall considered quite realistic. To cite only a very recent example, relative to one of the economies that we will study in chapter 4, Yilmazkuday and Akay (2008), have applied it to Turkey's real GDP quarterly data for the period 1987Q1:2002Q4.

They have successfully captured all of the recessionary periods determined by OECD's Composite Leading Indicators (Reference Turning Points and Component Series): the 1988-89 stagnation that signalled the drawbacks of the strategy based on export growth adopted during 1980's, the 1990-91 recession caused by the Gulf War, the 1994 recession motivated by a financial crisis, the 1998-1999 recession triggered by the Russian Crisis and deepened by the 1999 earthquake, and the 2001 recession that followed the financial and currency crises that occurred in November 2000 and February 2001.

In this section we have focused on the use of MS regime models in business cycles analysis, not only because it is at the origin of the use of these models in macroeconomics, but also because that is precisely our interest in this dissertation. However, it should be noted, as a final commentary, that MS regime models have also been used in other fields of economics: for example, as exchange rate models [Engel and Hakkio (1996)] or in the study of credibility issues [Sarantis and Piard (2004)], among many others. Also, it should be noted that the MS-regimes models are not the only option for modelling BCs nonlinearly: the asymmetries of business cycles are also captured by alternatives such as threshold models [Tiao and Tsay (1994)] and smooth transition auto-regression (STAR) models [Teräsvita and Anderson (1992)], among others.

3.3 Refinements of the original model

The previous section described the baseline MS-regimes model proposed by Hamilton (1989). However, many refinements to that model have been suggested since then. This section will present such improvements: higher-order-regime models, multivariate approaches, specific Markov Chains in a multivariate framework and time-varying transition probabilities. The section will end with the presentation of a generic Markov Switching regime model.

3.3.1 M-regime models

Hamilton's (1989) MS-regimes model considered only two regimes: expansions and contractions. Subsequent models have considered an unobservable regime variable $s_t \in \{1,...,M\}$ that may have up to M regimes representing the state of the business cycle.

There are a number of studies motivating such higher-order MS-regimes models. Sichel (1994) gives evidence that contractions in the business cycle are followed by short bursts of high-growth recovery periods that push output back to its pre-recession level, which are then followed by moderate-growth phases - which amounts to three regimes. Kim *et al.* (2005) also present a model that captures a post-recession bounce-back effect regarding the level of aggregate output. Although not specifying a proper three regime MS model, the included bounce-back term, apart from being statistically significant, has a large effect, showing that the permanent effects of recessions in the United States are much smaller than suggested by Hamilton (1989).

As regards theoretical motivations, the three phase pattern is consistent with Friedman's plucking down model; Friedman (1964) argued, "output [should be] viewed as bumping along the ceiling of maximum feasible output except that every now and then it is plucked down by a cyclical contraction… When subsequent recovery sets in, it tends to return output to the ceiling".

Formally, the adaptation from the 2-regimes MS model to the general case of a M regimes MS model may be stated as follows:

$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i), \qquad \sum_{i=1}^{2} p_{ij} = 1, \qquad \forall i, j = 1,2$ Equation 3-1 and

$P = \begin{bmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{bmatrix}$ Equation 3-2 now become

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i), \qquad \sum_{i=1}^{M} p_{ij} = 1, \qquad \forall i, j \in \{1, \dots, M\}$$ **Equation 3-3**

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1M} \\ p_{21} & p_{22} & \cdots & p_{2M} \\ \cdots & \cdots & \cdots & \cdots \\ p_{M1} & p_{M2} & \cdots & p_{MM} \end{bmatrix}$$ **Equation 3-4**

where $p_{iM} = 1 - p_{i1} - \dots - p_{i,M-1}$, for $i = 1, \dots, M$.

Despite the arguments put forward in favour of MS-regimes of order higher than 2 – and, specifically, in BCs analysis, of order of 3 – in the results presented in this dissertation only 2 regimes models will appear.

This is due to a number of reasons, from which we highlight two: first, parsimony is exceedingly valuable in situations such as ours in which the amount of data available is very scarce (see chapter 4); second, there is evidence in Artis *et al*. (2004a), Krolzig and Toro (2000) and Krolzig (2001) that after 1980 the third regime no longer appears to be relevant in the European BC – which turns out to be crucial for our choice of model, as we will necessarily (due to data constraints) study only a very recent period.

3.3.2 Multivariate approach – Markov Switching Vectorial Autoregressive models (MS-VAR)

Even tough Hamilton's (1989) MS regime model was capable of capturing nonlinearities and asymmetries in output growth, it could not reflect the idea of comovement among economic time series because it was univariate: this brought forward a second improvement: the extension of the MS-regimes models to a multivariate analysis.

Phillips (1991), Filardo and Gordon (1994) and Krolzig (1997a) were the first researchers that attempted to analyze the international business cycles using multivariate MS-regimes models, [see Krolzig (2001a)].

Extending the model presented in the previous section to a bivariate version in order to account for pairwise business cycle comparisons between country *a* and *b* results in

$$\begin{cases} y_{a,t} - \mu_{s_{a,t}} = A_{aa}(L)\left(y_{a,t-1} - \mu_{a,s_{a,t-1}}\right) + A_{ab}(L)\left(y_{b,t-1} - \mu_{b,s_{b,t-1}}\right) + \varepsilon_{a,t} \\ y_{b,t} - \mu_{s_{b,t}} = A_{ba}(L)\left(y_{a,t-1} - \mu_{a,s_{a,t-1}}\right) + A_{bb}(L)\left(y_{b,t-1} - \mu_{b,s_{b,t-1}}\right) + \varepsilon_{b,t} \end{cases}$$

Considering the way the states were defined for the univariate model, a new state variable $s_{ab,t}$ may be constructed as

$$s_{ab,t} = \begin{cases} 1 & s_{a,t} = 1 \wedge s_{b,t} = 1 \\ 2 & s_{a,t} = 0 \wedge s_{b,t} = 1 \\ 3 & s_{a,t} = 1 \wedge s_{b,t} = 0 \\ 4 & s_{a,t} = 0 \wedge s_{b,t} = 0 \end{cases}$$

which, in turn, originates a 4x4 transition matrix.

In the quantitative study conducted in this dissertation, in chapter 4, we will begin by estimating univariate MS-regime models for the countries under scrutiny and for the aggregate Euro Area. Yet, we will estimate a multivariate MS-2-regime model for a number of countries that supposedly form the core of the Euro Area, as a robustness check.

3.3.3 Specific Markov Chains in a multivariate framework

Multivariate MS regime models (or MS regime VAR models) may be specified with parameters depending on one common Markov Chain or depending on specific Markov Chains for each equation of the VAR. In terms of the previous section analytical example, the former case means that $s_{a,t}$ equals $s_{b,t}$, whereas the latter amounts to $s_{a,t}$ and $s_{b,t}$ being two distinct unobservable variables.

Assuming one single Markov Chain in a multivariate model imposes that every country switches regime simultaneously. As Anas et al. (2007) have shown, that assumption would imply a common cycle estimated so that the model adjusts itself in order to determine turning points that best fit the turning points of the average of the group of countries analyzed. In this sort of framework, the business cycle is defined as the common factor driving macroeconomic fluctuations of the countries under analysis. Assuming that the countries share the same turning points does not imply that they are synchronized with the common cycle: as Krolzig (2003) showed, it is possible that some countries are not affected by changes in regime, so that for country k, $\mu_{km} = \mu_k$, for all m.

In Phillips (1991), which is a case of a bivariate MS-regimes model with specific Markov Chains, as there are two possible states for each country, there will be four different combinations of these states in the Markov process. By imposing some restrictions on the transition matrix, Phillips (1991) manages to capture a great variety of cross-country business cycle transmissions. More recently, Psaradakis *et al.* (2005) try to model changing Granger causalities, also within the framework of a MS-regime model with a VAR specification.

Bengoechea and Quirós (2005), building on Phillips' (1991) model, present a model which is a linear combination of a model with two independent MS-regimes models with common transition probabilities and another model that assumes that both series are determined by just one MS component. The key parameter is, then, the one that defines the weight given to each of the alternative models.

Due to the data limitations cited above – and described below – this approach will not be pursued in this dissertation; yet, it should be useful in future studies as more data, with higher quality, is available for CEECs.

3.3.4 Time-varying transition probabilities

In Hamilton's (1989) MS-regimes model, the transition probabilities are time invariant. Another extention of this baseline model has consisted in abandoning the assumption of fixed transition probabilities (FTP) in favour of time-varying transition probabilities (TVTP).

As Filardo (1994) and Filardo and Gordon (1998) have argued, the FTP has the drawback of forcing the duration of the regimes to be constant, even if they actually vary over time. Filardo (1994) pioneered the extension of Hamilton's (1989) model to time-varying transition probabilities, highlighting two main reasons for his model to outperform a FTP one: first, the TVTP models allows the transition probabilities to rise just before an expansion or recession begins, and second the TVTP models captures temporal persistence better.

Filardo and Gordon (1998), moreover, claimed that after exiting from a deep recession, the economy will surely be less prone to fall back into a recession. Furthermore, they have argued that in the FTP model exogenous shocks or macroeconomic policies are not allowed to alter the expectation of how long an expansion or recession will linger.

Formally, in the TVTP model the transition matrix ($P = \begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}$ Equation 3-2 above) becomes time-dependent:

$$P = \begin{bmatrix} p_{11}(z_t) & 1-p_{11}(z_t) \\ 1-p_{22}(z_t) & p_{22}(z_t) \end{bmatrix}$$

where z_t is the information variable(s) driving the evolution of the unobserved regime. In short, the probability of a change in regime varies with movements in leading variables, z_t [Filardo (1994)].

In order to model the TVTP, a logistic function may used, as in Diebold et al. (1994) and Filardo (1994). In that case the transition probabilities are:

$$p_{11} = P(s_t = 1 \mid s_{t-1} = 1) = \exp(\alpha_1 + \beta_1 z_t) / (1 + \exp(\alpha_1 + \beta_1 z_t))$$
$$p_{22} = P(s_t = 2 \mid s_{t-1} = 2) = \exp(\alpha_2 + \beta_2 z_t) / (1 + \exp(\alpha_2 + \beta_2 z_t))$$

Alternatively, Simpson *et al.* (2001) used an exponential function but found that it does not have an economic interpretation as intuitive as the logistic. Nevertheless, they pointed out that it eliminates many of the numerical problems (namely non-convergence in estimation) that are sometimes found with the logistic function.

Alternatively, Filardo and Gordon (1998) use a latent variable version of the probit model, such that

$$\Pr(s_t = 1) = P(s_t^* \geq 0)$$

where s_t^* is a latent variable that includes the information variable vector z_t. Under this assumption, $p_{11}(z_t)$ and $p_{22}(z_t)$ will evolve according to a Normal cumulative function. Like Filardo and Gordon (1998), Kim et al. (2008) also rely on a probit specification for s_t but they extend the analysis to an M-regime endogenous switching model.

Instead of using leading indicators as the tradition founded by Filardo (1994) did, Durland and McCurdy (1994) specified a model of duration-dependent transition probabilities, *i.e.*, a model in which the longer the economy is in a recession, the smaller is the probability of staying in recession. More recently, Isogai *et al.* (2004) further develop the TVTP models, allowing the coefficients associated to the exogenous variables driving the time-variation in the transition probabilities to vary with time.

In this dissertation we will not present estimates of TVP models, as the already stressed scarcity of data precluded a proper estimation of such a highly parameterized class of models.

3.3.5 General specification of an MS-VAR model

To summarize the previous sections, and following Krolzig (1997b), each of the refinements individually presented above (with the exception of TVTP) can be considered altogether. This leads to the following model

$$y_t - \mu_{s_t} = A_{1,s_t}(\Delta y_{t-1} - \mu_{s_{t-1}}) + \dots + A_{p,s_t}(y_{t-p} - \mu_{s_{t-p}}) + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \sum{}_{s_t}\right)$$ **Equation 3-5**

where μ_{s_t}, A_{1,s_t}, …, A_{p,s_t} and $\sum{}_{s_t}$ are parameter shift functions that describe the regime dependence of the parameters μ, $A_1,\dots,A_p$ and $\sum$.

As regards transition probabilities,

$$p_{ij} = \Pr(S_{t+1} = j \mid S_t = i), \qquad \sum_{i=1}^{M} p_{ij} = 1, \qquad \forall i, j \in \{1,\dots,M\}$$ **Equation 3-6**

When there is a change in regime, the model presented in $y_t - \mu_{s_t} = A_{1,s_t}(\Delta y_{t-1} - \mu_{s_{t-1}}) + \dots + A_{p,s_t}(y_{t-p} - \mu_{s_{t-p}}) + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \sum{}_{s_t}\right)$ Equation 3-5 implies an immediate one-time jump on the process mean. A slight modification to a model with intercept enables the mean to smoothly approach the new level after a transition in the regime:

$$y_t = v_{s_t} + A_{1,s_t} y_{t-1} + \dots + A_{p,s_t} y_{t-p} + \varepsilon_t$$ **Equation 3-7**

In this general specification, all the parameters are conditioned on the state of the Markov chain. However, it may be advisable to consider some of the models' parameters as regime invariant. This would lead to particular formulations of the MS regime VAR model, in which multiple combinations of time-invariant and switching parameters are possible – involving the autoregressive parameters, the mean or intercepts, and the error term (with its variance-covariance matrix being hetero- or homoskedastic).

Krolzig (1997b) has established a notation that became popular to specify each model: i) Markov-Switching Mean, ii) Markov-Switching Intercept, iii) Markov-Switching Autoregressive parameters and iv) Markov-Switching Heteroskedasticity.

In Table 3-1 we present Krolzig's summary of all these possible variations of the MS-regime model.

		MSM μ varying	**MSI specification**		
			μ invariant	***v* varying**	***v* invariant**
A_j invariant	**Σ invariant**	MSM-VAR	*linear* MVAR	MSI-VAR	*linear* VAR
	Σ varying	MSMH-VAR	MSH-MVAR	MSIH-VAR	MSH-VAR
A_j varying	**Σ invariant**	MSMA-VAR	MSA-MVAR	MSIA-VAR	MSA-VAR
	Σ varying	MSMAH-VAR	MSAH-MVAR	MSIAH-VAR	MSAH-VAR

Table 3-1: Markov-Switching Vector Autoregressive Models
Source: Krolzig (1997b)

4 Data and Results

4.1 Econometric Motivation

The aim of this dissertation is to analyse the business cycle synchronization between the Euro Area and the countries that have recently become part of the European Union but are not yet part of European Monetary Union (EMU), mainly CEECs.

In order to compute the synchronization indicators discussed in section 2.4.2, we have chosen to use a parametric nonlinear time series model, specifically the MS regime model described in chapter 3 to compute the cyclical turning points and the state variables of recession and expansion.

The motivation for our choice of econometric approach may be perceived from a comparative analysis of Table 2-3, Table 2-1 and Table 2-2.

Firstly, Table 2-3 reviews papers that deal with BCs synchronization between the Euro Area and the new EU members such as those that we aim to study. Three features of these studies are of interest for us. First, it turns out that most papers use quantitative methods mainly involving some correlation coefficient. Second, many papers do not consider the whole Euro Area but only a small part of its member-states as proxy for the Area cyclical condition. Third, some studies choose a *deviation cycle* framework.

From Table 2-1, we retain the papers by Beine et al. (2003), Garnier (2003), Artis *et al.* (2004a) and Altavilla (2004), whereas from Table 2-2, we pay a special attention to Massman and Mitchell (2004). These are the studies that deal with the synchronization between EMU member-states following the *classical cycle* approach that we choose to pursue in this dissertation. We repeat the basic information regarding these papers in table 4-1 for the reader's convenience:

Study	Data used	Mesure of cycle	Convergence measure	Conclusions
Beine et al. (2003)	Unemployment, FIN, FRA, GER, ITA, NLD, NOR, PRT, SPA, SWI, SWE, UK, quarterly 1975–1996	Recession probabilities from a Markov switching VAR model	Several indicators based on recession probabilities similar to concordance indices	More synchronization amongst EMU members, compared to European periphery
Garnier (2003)	Monthly IP for 18 countries, 1962–2001; before and after EMS	Analysis is based on various characteristics (including concordance index) of classical cycle determined by BB procedure	Comparison with cycles of Germany and US	Core group of euro countries (which does not include Belgium) shows increased similarity with German cycle
Artis et al. (2004a)	Industrial production, AUT, BEL, FRA, GER, ITA, NLD, SPA, 1970–1996, monthly	Probability of being in a recession based on Markov switching models	Correlation, contingency coefficient, variance decomposition	Considerable commonality but also important domestic (non-EU) component
Altavilla (2004)	GDP of BEL, FRA, GER, ITA, SPA, UK, US 1980–2002, quarterly	Classical and deviation cycles based on BB and Harding–Pagan procedures; trend for deviation cycle determined using HP and BP filters; for classical cycle Markov switching model is used	Characteristics of cycles (like duration, amplitude, steepness) and (correlation of) concordance measure compared with euro area	Deviation cycles of EMU countries are reasonably aligned, but classical cycles diverge more; after 1991 EMU countries became more synchronized
Massmann and Mitchell (2004)	OECD data of industrial production, 1961:1-2001:8; All euro area countries.	Deviation cycles extracted alternatively via three parametric methods (BN, UC, TIM) and four nonparametric methods (MA, HP, BK, PAT); Classical cycles using one measure proposed by Harding & Pagan.	Pairwise contemporaneous correlations and standard deviations using GMM; Rolling correlation coefficient.	Although empirical inference about individual euro area business cycles is found to be sensitive to the measure of the business cycle, the measure of convergence exhibits common features across the alternative measures of cycle. Euro area has been characterised by periods of convergence, and periods of divergence. Evidence suggest that euro area has entered a period of convergence after the period of diverge in the early 90s. Some evidence that over the past 20 years correlations on average tended to increase.

Table 4-1: Studies on Business Cycle Synchronization in the Euro Area which focus on classical cycles
Source: Gouveia and Correia (2007) and de Haan *et al.* (2008)

In these papers the *classical cycle* is determined by either a parametric or a non-parametric approach (in practice by Markov Switching regime models or by the BBQ algorithm). And synchronization is measured by a variety of indicators such as the ones that we have chosen to work with – *contingency* index, *concordance* index, BCs' characteristics (such as amplitude, duration and steepness).

What is clear from this overall assessment of the literature of BCs synchronization involving the Euro Area is that, to the best of our knowledge, the methodological approach that we chose has not been thoroughly applied to the new EU member states (namely the CEECs) in the assessment of the synchronization of their business cycles with that of the Euro Area.

Hence, our dissertation fills a gap in the literature, as we (i) study BCs synchronization between the CEECs that have entered the EMU recently but not the Euro Area, (ii) constructing the BCs turning points within a *classical cycle* approach based on a MS-regime model and (iii) assessing synchronization with a number of indicators suggested by or in the spirit of Harding and Pagan that go beyond simple correlation coefficients – Pearson's *contingency* index, *concordance* indexes, statistical tests on these indexes and business cycles characteristics. Moreover, we compare the BCs of the CEECs with the EMU cycle and then look at the BC of the EMU core countries as a robustness check.

4.2 Data

The following table summarizes the successive enlargements of the European Union and the dates at which its member-states joined the European Monetary Union, *i.e.* adopted the Euro.

Adoption of the EURO Currency

Countries that have adhered to the European Union		1999	2001	2007	2008
1957	Germany	√			
	Belgium	√			
	France	√			
	Italy	√			
	Luxembourg	√			
	Netherlands	√			
1973	Denmark				
	Ireland	√			
	United Kingdom				
1981	Greece		√		
1986	Spain	√			
	Portugal	√			
1995	Austria	√			
	Finland	√			
	Sweden				
2004	Cyprus				√
	Slovakia				
	Slovenia			√	
	Estonia				
	Hungary				
	Latvia				
	Lithuania				
	Malta				√
	Poland				
	Czech Republic				
2007	Romania				
	Bulgary				

Table 4-2: EU enlargements and adoption of the Euro
EU countries that have not adopted the Euro

As shown in the Table, among the countries that have integrated the EU more than a decade ago, Denmark, the United Kingdom and Sweden have not yet entered the EMU. The focus of this dissertation, however, are those countries that have adhered to the EU after 2004 but not the Euro Area. Hence, the countries under analysis are the Slovak Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Czech Republic, Romania and Bulgaria. Moreover, we have considered of interest to spread the analysis in order to cover three countries that are currently candidates to the EU – Turkey, Croatia and the Former Yugoslav Republic of Macedonia.

All the quantitative analysis is conducted subsequently and independently using time series of real Gross Domestic Product (GDP), first, and Industry Production Index (IPI), secondly. This is motivated by conclusions that we have reached in chapter 2: (i) the choice of measures of the aggregate economic activity is not unambiguous (section 2.2); and (ii) the diverging results about the degree of synchronization in a variety of papers may be explained, among other causes, by the use of different data sets (section 2.4.1).

The quantitative analysis in this chapter implements univariate Markov Switching regimes models in the identification of business cycles phases and turning points and then assesses the synchronization between the cycles of the CEECs and the cycle of the Euro Area with Harding and Pagan's tools. This analysis is thus conducted for two datasets, GDP and IPI, in order to find whether the results differ markedly.

Finally, as a robustness check, the regime chronology of a group of countries representing the core of the Euro Area will be estimated, and the synchronization between this EMU core and the CEECs' cycles will be assessed.

We have determined the group of countries that should constitute the core of the Euro Area on the basis of the literature. Following Savva *et al.* (2007), Artis (2003) and Artis and Zhang (1998), we consider that the core consists of Austria, Belgium, France, Germany and the Netherlands.

4.2.1 GDP

The Euro Area quarterly GDP was collected from the latest available update (8^{th}) of the Area-wide database Model (which already includes Cyprus and Malta), whereas the data for the remaining countries has been taken from the International Financial Statistics database of the International Monetary Fund.

Studying the CEECs involves a very important difficulty with the data. In fact, data have poor quality for most of the CEECs and credible statistics from international databases are only available since the mid 1990's. This is evidently explained by the fact that these countries went through a political and economic transition period after the demise of socialism at the beginning of the 1990s.

Problems of data availability forced us to put aside some of the countries that we intended to study: this was the case of Romania, Bulgaria, Croatia and the Former Yugoslav Republic of Macedonia. For the others CEECs, we have considered data since 1995Q1, which was the largest common data span available. Our sample period ends at 2007Q4, even though for almost all countries data through 2008Q1 were available, as there was no such data available for Turkey.

Table 7-1 in the Annex shows the codes and the sample period for which data was available for each time series. As the data was originally in current prices, we have used the GDP deflator to transform nominal GDP into real GDP.

The original data of practically all the countries had not been seasonally adjusted, so we have done a seasonal adjustment using the module X12arima of GiveWin 2.30. Despite estimations are conducted for data after 1995, we have performed the seasonal adjustment of all the available time series, which has the advantage of allowing to disregard the initial observations of the adjusted series, typically characterised by abnormal oscillatory behaviour.

Figure 7-1 through Figure 7-13present a comparison of the quarterly seasonally and not seasonally adjusted real GDP for all countries[1].

After seasonally adjustment of the data, we have submitted all time series to the ADF[2] unit root test using the selected sample period (1995Q1:2007Q4). Table 7-2 in the annex shows the results of this test. At a significance level of 7.5%, for every country the null of a unit root in the first differences of the logarithm of the quarterly seasonally adjusted GDP may be rejected, regardless of the inclusion of a deterministic trend or not. The only exception is the Slovak Republic, in which case the test including a constant term does not allow rejection of the null of a unit root for the first difference of the log of real GDP, at a significance level of 7.5%. We have then proceeded to model all series in first differences: $\Delta y_t = 100 * \ln(Y_t / Y_{t-1})$, i.e., we have specified MS-regimes models for the growth rate of real GDP for all countries.

4.2.2 Industrial Production Index

Monthly IPI data were also obtained from the International Financial Statistics database of the International Monetary Fund: Table 7-13 presents a summary of the variables' codes and their time span.

Estonia and Latvia do not have data for the IPI, so they had to be excluded from the analysis; additionally, we were not able to find some data-points for Croatia's IPI, so this time series had also to be disregarded. The largest sample period common to all the countries' IPI is 1993M1:2008M7. The exceptions were Bulgaria and Macedonia (data

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[1] There was no need to adjust the GDP time series of France, Germany and the Netherlands.

[2] The null hypothesis is $H_o : \phi = 1$ in the regression:

$y_t = \alpha + \phi y_{t-1} + \sum_{j=1}^{p-1} \varphi_j \Delta y_{t-j} + \varepsilon_t$, $\varepsilon_t \sim WN$, if one just wants to consider a constant term or

$y_t = \alpha + \delta t + \phi y_{t-1} + \sum_{j=1}^{p-1} \varphi_j \Delta y_{t-j} + \varepsilon_t$, if a determinist trend is to be included beginning in 2000) as well as Lithuania (data beginning in 1997), which were excluded from the analysis.

Thus, the IPI estimations will consider data from the Czech Republic, Hungary, Poland, Romania, the Slovak Republic and Turkey. The Euro Area's IPI time series in the IMF's IFS database begins in 1998M1, so we had to build an IPI time-series from 1998 backwardly until 1993M1 using data taken from the Eurostat database[3].

Romania's IPI was the only needing to be seasonally adjusted: the comparison between the seasonally adjusted and non adjusted log of IPI is presented in Figure 7-24. In turn, Figure 7-25 and Figure 7-26 show the log IPI for the CEECs and the core Euro Area countries, respectively.

Table 7-14 presents the results of the ADF stationarity test, clearly showing that at a level of significance of 1% the null of a unit root may be rejected for the first difference of the log of IPI for all countries. As such, these time series will also be modelled in first differences of their logs – *i.e.* growth rates – with estimations performed for the sample 1993M2:2008M7.

4.3 Estimation

All the estimation results presented have been generated using the Ox console version 3.4 (see Doornik (2007)), and the MSVAR package developed by Krolzig (1998). In what follows we will use the notation presented in section 3.3.5, which has been based in Krolzig (1997b) and is thus consistent with the outputs of the used econometric package.

[3] The Eurostat Euro Area's industrial production index includes the same 11 countries that are considered in the IFS database.

4.3.1 GDP

4.3.1.1 Euro Area

Given that the number of available observations is relatively small, we consider models with constant matrix of variances and covariances $\sum$ and non regime-dependent autoregressive parameters (otherwise, the computational burden would be very high, especially in the case of multivariate models[1]). Hence, in the taxonomy of Table 3-1, our models for real GDP growth are of the class of MSM-AR or MSM-VAR.

The model specified for the Euro Area was a MSM(m)-AR(p) with a number of regimes *m=2* (regime 1 representing recession, and regime 2 representing expansion). Regarding the number of lags p, we have adopted a general-to-specific approach, basing the choice on comparisons of the Hannan Quinn criterion value.

Table 4-3: Hannan Quinn criterion for Euro Area MSM(2)-AR(p) shows that the adequate choice for the number of autoregressive parameters seems to be *p=3,* as the Hannan Quinn criterion reaches its lowest value at that lag extension.

	EURO AREA - 1995Q2:2007Q4			
	MSM(2)-AR(1)	MSM(2)-AR(2)	MSM(2)-AR(3)	MSM(2)-AR(4)
HQ criterion	-8.7175	-8.7204	-8.7264	-8.5348

Table 4-3: Hannan Quinn criterion for Euro Area MSM(2)-AR(p), GDP Data

The estimates presented in Table 4-4 show that during this sample period the model does not estimate any recession, as no regime of a negative growth rate of real GDP is detected. This turns out to be consistent with the data: as can be observed in the first panel of Figure 4-1, the growth rate of the Euro Area's GDP was always positive, with the only exception

[1] The drawback of considering $\sum$ constant is that it will not be possible to ascertain the stylized fact documented by French and Sichel (1993) for the United States that stated that recessions and expansions have different volatilities, with larger fluctuations of GDP during recessions.

of the second quarter of 2003 (negative growth of -0.0022%). In this case, regime 1 may be interpreted as a low growth regime, whereas regime 2 as a normal growth regime.

	MSM(2)-AR(3) 1995Q2:2007Q4
regime dependent mean	
$\mu 1$	0.0029
t-value	1.8132
$\mu 2$	0.0071
t-value	4.3327
Ergodic Probability	
regime 1	0.3984
regime 2	0.6016
Duration	
regime 1	1.9
regime 2	2.87
Standard error	
σ	0.0013037

Table 4-4: Summary results of a MSM (2)-AR(3) for the Euro Area, 1995Q2:2007Q4, GDP Data

Table 4-4 also shows the ergodic probability – which can also be called stationary probability, as it represents the probability of leaving state *j* being equal to the probability of entering the same state *j*: as the table shows, in the long run the probability of the Euro Area being in a normal growth regime is independent of the initial state and equals 60.16%. As is well-known, these probabilities are easily calculated from the transition probability matrix, which in this case is:

$$\hat{p}_{ij} = \begin{bmatrix} 0.4740 & 0.5260 \\ 0.3483 & 0.6517 \end{bmatrix}$$

The regimes can now be reconstructed by inferring the probabilities of the unobserved regimes conditional on the available information set. This is done by the means of filtered regime probabilities and smoothed regime probabilities. While the former make an optimal inference on the state variable at time *t* using just the information up until that period,

$\Pr(s_t = m \mid Y_t)$, the latter uses the full sample information $\Pr(s_t = m \mid Y_T)$, with m representing the regime. The next graphic presents both probabilities. The classification rule $\Pr(s_t = 1 \mid Y_T) > 0.5$ originates the chronology of regimes shown in detail in Table 7-3:

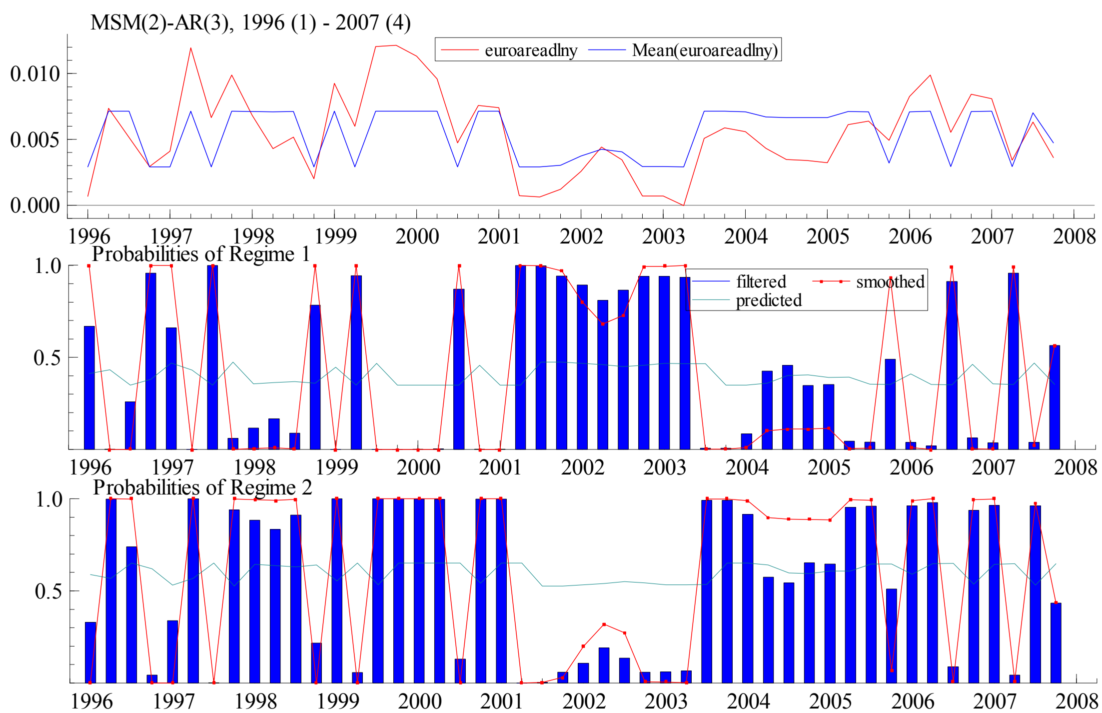

Figure 4-1: Euro Area regime chronology, GDP data

4.3.1.2 Individual countries – univariate approach

We have proceeded analogously to all the individual countries under analysis: assume a 2 regime model, choose the auto-regressive extension on the basis of the Hannan-Quiinn criterion and estimate the model inferring the chronology of regimes.

The Hannan Quinn criterion values obtained for each lag *p* for each country are as follows:

	1995Q2:2007Q4			
	MSM(2)-AR(1)	MSM(2)-AR(2)	MSM(2)-AR(3)	MSM(2)-AR(4)
Czech Republic	-6.3965	[-6.6072]	-6.7704	**-6.9045**
Estonia	**[-5.7802]**	-5.7405	-5.6791	-5.608
Hungary	-6.6107	-6.6064	-6.5954	**[-6.742]**
Latvia	-5.8982	**[-6.0689]**	-6.0197	-6.0191
Lithuania	-5.0459	[-5.0774]	**-5.0967**	-5.0516
Poland	-5.2883	**[-5.5114]**	-5.4958	-5.4648
Slovak Republic	**[-5.2507]**	-5.1801	-5.1701	-5.0984
Turkey	**[-2.6582]**	-2.5824	-2.5224	-2.4405

Table 4-5: Hannan Quinn criterion for MSM(2)-AR(p), GDP Data - Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Turkey

Note: the values in bold show the smallest Hannan Quinn criterion; the values in brackets show which model was chosen

Although the Hannan Quinn criterion would indicate that for the Czech Republic and Lithuania the number of lags ought to be 4 and 2, respectively, different results were chosen. For the case of the Czech Republic, the Figure 7-14, which displays the correlogram of the residuals, suggests that there is more autocorrelation for an AR (4) than for an AR(2), and so p=2 has been chosen. For Lithuania, we have chosen an AR (2), even though the Hannan Quinn criterion has a smaller value for an AR (3), because in the latter, differently than in the former, all autoregressive coefficients are statistically significant and we have valued parsimony.

The estimation results for the sample period (1995Q2-2007Q4) are summarized in the following table. Hungary and Lithuania are the two only countries for which the first regime is estimated as a recessionary regime, whereas for all the others – like in the Euro Area case – the first regime is one of lower growth and the second one is one of normal growth. For most countries, the growth rate for the second regime reaches levels of around 7% per year.

In the cases of Hungary and Lithuania, the ergodic (unconditional) probability of regime 1 and the expected number of quarters that regime 1 lasts, mean that recessions have very low persistence. The ergodic probabilities of regime 1 are too small in comparison to the same probabilities for regime 2, thus signalling that in the long run these countries tend to be in an expansionary state. In fact, Hungary and Lithuania has negative growth rates in 3 out of 47 observations, and in 5 out of 49 observations, respectively.

In the remaining countries, the ergodic probabilities and both regimes' durations tend to level out, which is probably associated to the fact that regime 1 does not consist of a recession, but rather a low positive growth regime.

	Czech Republic	Estonia	Hungary	Latvia	Lithuania	Poland	Slovak Republic	Turkey
	MSM(2)-AR(2)	MSM(2)-AR(1)	MSM(2)-AR(4)	MSM(2)-AR(2)	MSM(2)-AR(2)	MSM(2)-AR(2)	MSM(2)-AR(1)	MSM(2)-AR(1)
regime dependent mean								
μ1	0.0013	0.0013	-0.0132	0.0058	-0.0065	0.0046	0.0087	0.0154
t-value	0.3587	0.2047	-1.6997	1.5622	-1.1562	2.8192	1.4882	0.3578
μ2	0.0184	0.0198	0.0104	0.0256	0.0186	0.017	0.0197	0.0183
t-value	4.353	4.7239	1.8442	6.3448	7.0066	7.0954	2.8544	0.36
Ergodic Probability								
regime 1	0.4892	0.1343	0.0448	0.3755	0.0913	0.4561	0.5292	0.5027
regime 2	0.5108	0.8657	0.9552	0.6245	0.9087	0.5439	0.4708	0.4973
Duration								
regime 1	15.03	3.71	1.99	2.03	2.93	4.12	23.07	3.89
regime 2	15.7	23.9	42.38	3.37	29.1	4.92	20.53	3.85
Standard error								
σ	0.0058383	0.010133	0.0053964	0.0054272	0.013843	0.0097126	0.014022	0.054356

Table 4-6: Summary results of a MSM (2)-AR(p) for Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Turkey, 1995Q2:2007Q4, GDP Data

The optimal inference on the smoothed probabilities of each regime at period *t* (using the full sample information) leads to the business cycle chronologies shown in Figure 7-15 through Figure 7-22 and Table 7-3 trough Table 7-11 in the Annex.

4.3.1.3 Synchronization

We now look, quantitatively, at the synchronization between the CEECs business cycles (BCs) and the Euro Area's BC. As mentioned above, three measures of synchronization will be assessed: i) Pearson's corrected contingency coefficient, ii) business cycle's characteristics and a iii) *concordance* index and an associated statistical test.

A first approach to the assessment of synchronization consists of computing Pearson's corrected contingency coefficient, which allows for evaluating the comovement between the countries' BCs: if countries have complete cyclical dependence, they will be in the same regime for every period *t* and Pearson's corrected coefficient will be 100. On the other hand, if there is no contemporaneous relationship between business cycle regimes, Pearson's coefficient will be zero.

	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Poland	Slovak Rep	Turkey	Euro Area
Czech Rep	100								
Estonia	39.134787	100							
Hungary	2.1799741	14.0565	100						
Latvia	43.076022	47.24145	21.30434	100					
Lithuania	31.646054	69.92025	11.22722	31.73546	100				
Poland	46.860455	21.28524	9.947712	7.117238	2.758278	100			
Slovak Rep	89.389429	39.13479	23.12212	31.52872	31.64605	35.90036	100		
Turkey	4.1682915	26.53943	4.681325	0.29442	26.2092	27.56989	23.49793	100	
Euro area	35.480582	7.806546	29.73897	21.48515	8.400399	25.46001	23.5584	42.55314	100

Table 4-7: Pearson's corrected contingency coefficient, GDP data

The highest contingency index is observed in the case of the Czech Republic and Slovak Republic BCs, whereas the smallest is observed between Turkey and Latvia's BCs. The contingency indexes of the Euro Area *vis-à-vis* every individual country are relatively low, and one striking result is that Turkey seems to be the country with the most synchronized BC. The correlation between the Euro Area BC and the Czech Republic's BC is not markedly smaller, while a group of countries including Hungary, Poland, the Slovak Republic (and, to a lesser extent, Latvia) features an intermediate level of correlation.

We now turn to the computation and comparison of the main BCs' characteristics explained in section 2.4.1. This analysis is motivated by the idea that synchronization (defined by similarity of regimes in each period) is a necessary but not sufficient condition to determine that countries would face low costs when entering a single currency area. As stated in Camacho *et al.* (2008, page 2166) "it may happen that if the shapes of their cycles are different, supranational policy reactions against recessions may be too accommodative for countries that change the business cycle phases sharply and too tight for countries whose state changes are smooth. These policies may also last too long for countries with shorter duration of cycles and too short for countries with longer cycles. Finally, the strength of common stabilization policies may be insufficient for those countries with deeper cycles and disproportionate for countries with mild cycles".

The results are as follows (see section 2.1 for an overview and explanation of the acronyms):

	Dpt	Dtp	AMPpt	AMPtp	STEEPpt	STEEPtp	CMpt	CMtp
Czech	15.5	18	0.0472	0.2999	0.0030	0.0167	0.3662	2.6994
Estonia	4	42	-0.0013	0.8425	-0.0003	0.0201	-0.0026	17.6925
Hungary	1.5	44	-0.0088	0.4927	-0.0059	0.0112	-0.0066	10.8390
Latvia	2.375	3.75	0.0156	0.0963	0.0066	0.0257	0.0186	0.1806
Lithuania	4	45	-0.0337	0.8135	-0.0084	0.0181	-0.0675	18.3036
Poland	5.5	6.75	0.0105	0.1239	0.0019	0.0184	0.0289	0.4182
Slovak	30	20	0.2415	0.4275	0.0081	0.0214	3.6229	4.2749
Turkey	9.25	3.25	0.0791	0.1290	0.0086	0.0397	0.3660	0.2096
Euro Area	2.11	2.8	0.0065	0.0204	0.0031	0.0073	0.0068	0.0286

Table 4-8: Business cycles' characteristics, GDP Data

The main conclusions are the following.

First, as was already analysed in Table 4-6, Hungary and Lithuania are the only countries in which the first regime corresponds to recessionary periods: in Table 4-8 these are the only countries (apart from Estonia) that have negative amplitude from peak-to-trough. Regarding the negative result for the Estonian AMP_{PT}, this might signal the fact that the

MSM(2)-AR(1) failed to capture the negative growth that occurred from 1998:Q4 to 1999:Q2 (see Figure 7-16).

Second, Estonia, Hungary and Lithuania have rather similar BCs characteristics, especially as regards the durations of phases and their CM_{TP} in expansionary periods (which proxies a welfare gain and are the highest).

Third, Hungary, Poland and the Czech Republic have similar rates at which a peak is reached once an expansionary period has begun (as measured by $STEEP_{TP}$).

The Euro Area has the shortest durations for both regimes. This table confirms that in the period under analysis (1995Q2-2007Q4) there has been no recessionary regime. The welfare gains of the Eurozone are relatively small when compared to other countries, which signals a more stable behaviour of the business cycle – a natural feature of larger Areas. Additionally, the Euro Area's STEEP values are the smallest for all countries considered, showing that the Area moves slowly from one turning point to the other.

Finally, we have computed the *concordance* index as defined by Harding and Pagan (2006) for the Euro Area *vis-à-vis* the CEECs countries. The results are depicted in Table 4-9. Overall, the results are similar for all countries and centre around 0.55.

We then computed the mean corrected *concordance* index, thus obtaining a measure of synchronization that is not affected by its expected value. With this measure the results change markedly, with Turkey and the Czech Republic having the highest levels of concordance with the Euro Area.

We now move to the statistical test derived at the end of section 2.4.2, in order to refine our conclusions on BCs synchronizations. In the test, the null is that the two considered BCs are independent, and the standardized *concordance* index can be read as a *t*-value statistic for this test.

	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Poland	Slovak Rep	Turkey
CI	0.5957447	0.5531915	0.5319149	0.5957447	0.5957447	0.5957447	0.5531915	0.5957447
Mean Corrected CI	0.1222273	-0.018108	-0.051607	0.0733364	0.016297	0.0896333	0.0796741	0.1385242
Standardized CI	1.791342	-0.405008	-4.337444	1.127827	0.645543	1.166925	1.179376	2.491488
(p-value)	0.08	0.6874	0.0001	0.2654	0.5219	0.2494	0.2444	0.0165

Table 4-9: *Concordance* Index with the Euro Area, GDP Data

The results for the standardized *concordance* index show that the null hypothesis of independence between these countries' business cycles and that of the Euro area can only be rejected in the cases of Hungary, Turkey and (albeit at a somewhat too large significance level of 8%) the Czech Republic.

4.3.1.4 Synchronization with the Euro Area Core – multivariate approach

As mentioned before, as a robustness check we have adopted a multivariate Markov Switching regime model in order to extract the common BC of the core of the Euro Area. For that purpose we have estimated a MSM(2)-VAR(p) model for a group comprising Austria, Belgium, France, Germany and Netherlands.

Following the same information criterion as above, which results are shown in Table 4-10, we have chosen a MSM(2)-VAR(1) model.

	EURO AREA Core - 1995Q2:2007Q4			
	MSM(2)-VAR(1)	MSM(2)-VAR(2)	MSM(2)-VAR(3)	MSM(2)-VAR(4)
HQ criterion	-35.383	-34.9151	-33.8454	-33.3739

Table 4-10: Hannan Quinn criterion for Euro Area Core MSM(2)-VAR(p), GDP Data

Consistently with the results for the Euro Area as a whole, neither of the regimes denotes recessionary periods, as can be seen in Table 4-11, and, also as before, the duration of regimes tends to level out.

	MSM(2)-VAR(1) 1995Q2:2007Q4				
	Austria	Belgium	France	Germany	Netherlands
regime dependent mean					
μ1	0.007125	0.002724	0.004353	0.000769	0.004013
t-value	3.6097	1.4007	3.3898	0.7515	2.9759
μ2	0.006152	0.008379	0.006611	0.006924	0.010165
t-value	1.91	2.7234	3.3362	3.8503	4.8691
Ergodic Probability					
regime 1			0.4687		
regime 2			0.5313		
Duration					
regime 1			7.23		
regime 2			8.2		
Standard error					
σ	0.008442	0.009681	0.004061	0.003688	0.003712

Table 4-11: Summary results of a MSM (2)-VAR(1) for the Euro Area Core, 1995Q2:2007Q4, GDP Data

The specific regime chronology generated by this model is depicted in Figure 7-23 and analysed in Table 7-12.

We then computed the *concordance* index between the Euro Area core BC resulting from the MSM(2)-VAR(1) model, and the CEECs' BCs. As Table 4-12 shows, the countries that have higher *concordance* indexes with the Euro Area may not be considered concordant with the Euro Area's Core. For example, despite having the third biggest mean corrected *concordance* index, the Czech Republic has a standardized CI that does not allow rejection of the null of independence.

Overall, the countries that may be considered as having BCs concordant with the Euro Area's core business cycle are the Slovak Republic and Poland.

	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Poland	Slovak Rep	Turkey
CI	0.6170213	0.5319149	0.5106383	0.5319149	0.4893617	0.787234	0.7021277	0.4468085
Mean Corrected CI	0.1258488	0.0081485	-0.017202	0.0244455	-0.037121	0.2851969	0.2109552	-0.038932
Standardized CI	1.155611	0.172483	-0.4682	0.294286	-1.184532	3.760479	2.357552	-0.403622
(p-value)	0.2539	0.8638	0.6419	0.7699	0.2424	0.0005	0.0228	0.6884

Table 4-12: *Concordance* Index with the Euro Area Core, GDP Data

4.3.1.5 Discussion

This section briefly compares the results obtained in the previous sections with those in the relevant literature. In order to do so, we have adapted the literature surveys in Fidrmuc and Korhonen (2003a, 2006). The following table summarizes the bulk of the papers they surveyed and that have used GDP time series, including in its first row the main findings of our own.

Table 4-13 shows a marked variety of results, which renders very hard any analytical summary. However, one can tentatively say that Hungary seems to be the country most often identified as having a BC synchronized with the Euro Area's. Moreover, it could be argued that Slovenia, Poland and the Czech Republic, albeit to a lesser extent, constitute a second group of countries with BCs relatively well synchronized with the Euro Area's.

Interestingly, the results in Boone and Maurel (1999) – who have used Germany as a proxy for the core of the Euro Area – seem to be the study with results more consistent with those obtained in this dissertation. In fact, their results are similar to the ones that we have obtained for our core of Euro Area countries: Poland and the Slovak Republic exhibit the highest levels of synchronization.

Since most studies do not look at Turkey, it is quite difficult to determine how idiosyncratic is our result that Turkey's business cycle seems highly synchronized with the Euro Area's. Overall, it seems fair to say that this dissertation's results mimic fairly well the results in at least some parts of the literature.

Study, year of publication	Methodology and variables	Acceding countries	Comparison country/area	Period analyzed	Conclusions
Present dissertation	Analysis is based on various characteristics (including concordance index) of GDP's classical cycle determined by Markov Switching model	CZE, EST, HU, LV, LT, PL, SL, TRK	Euro area and euro area core	Q2:1995-Q4:2007	CZE, HU and TRK's Business Cycle is proved to be synchronized with the Euro Area, whereas PL and SL are synchronized with the core of the Euro Area.
Boone and Maurel (1999)	Share of changes in unemployment rate explained by European or German shocks and correlation of their impulse response functions	CZE, HU, PL, SL	EU and DE	M1:1991-M12:1997	PL and SL have the highest correlations of responses to a German shock, and their business cycles are similar to the German one.
Fidrmuc and Korhonen (2003b)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CRO, CZE, EST, HU, LV, LT, PL, ROM, SL, SI	Euro area and euro area countries	Q2:1993-Q4:2000	correlation of supply shocks. HU has the highest correlation of demand shocks; for CZE and SI they are quite low and for KV and LT they are negatively correlated. Adjustment of output to both shocks is similar to those
Frenkel and Nickell (2002)	SVAR (correlation of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, PL, SL, SI	FRA, DE, and IT	Q1:1993-Q4:2001	CZ, SI and HU's shocks are as correlated with the biggest EMU countries as the shocks of the smaller countries of the EU that have adopted the euro.
Babetski et al. (2004)	SVAR (time-varying correlation coefficients of supply and demand shocks), GDP and prices	BLG, CZE, EST, HU, LV, LT, PL, ROM, SL, SI	EU and DE	Q1:1990-Q4:2000	The correlation of demand shocks between acceding countries and EU has increased but there has been divergence when it comes to supply shocks
Darvas and Szapáry (2008)	Cycle correlation with euro area, leads/lags, volatility, persistence of the cycle and a measure of impulse–response: GDP; measures of industry, exports, consumption and services	ES, CZE, HU, LV, LT, PL, SI	AUS, BLG, FRA, FLD, DE, IRL, IT, SP, PT	1993-1997; 1998-2002	HU, PL and SI have achieved high degree of synchronization for GDP, industry and exports, but not for consumption and services. Following them are CZE and SL.
Blaszkiewicz and Przemyslaw (2003)	Business cycle correlations, GDP	BLG, ROM, CZE, HU, LA, LT, PL, DL, SI	Euro Area countries	1992-2002	With the exception of HU and SI, measures of real activity comovements point to weak or even negative correlations of shocks in the euro area and acceding countries
Traistaru (2004)	Business cycle correlation, GDP	CZE, EST, HUN, LV, LT, PL, SI, SL	Euro Area countries	Q1:1993-Q2:2003	Business Cycles correlation are the highest for HU, SI and PL
Furceri and Karras (2006)	Business cycle correlation, GDP	CZE, ES, CY, LV, LT, HU, MLT, PL, SL, SI, BLG, CRO, TRK, FYROM	Euro Area	Q1:1993-Q4:2002	SI, CY and HU show high degree of synchronization with the Euro Area; LV and ES show low correlation with the Euro Area; RO, TRK and CRO sistematically show negative correlation.

Table 4-13: Survey regarding the synchronization of CEECs with the Euro Area using GDP data
Note: Adaptation of the survey presented in Fidrmuc and Korhonen (2003a, 2006)

4.3.2 IPI

4.3.2.1 The Euro Area

In contrast to the estimation strategy pursued for the GDP data, in this section we use a different model: accordingly to Krolzig's (1997b) mnemonic, presented in section 3.3.5, we estimate MSMH(2)-VAR(p) models (where $\sum$ is regime dependent). This is possible because, due to its monthly periodicity, we now have almost 4 times as many observations. And it may be useful, as this class of models allows for capturing the fact that recessions seem to be more volatile than expansions, as French and Sichel (1993) have documented for the United States.

The steps of the econometric strategy are, however, precisely the same as in the quantitative assessment of the GDP time series. The Hannan Quinn information criterion values, shown in table 4-14, suggest choosing an MSMH(2)-AR(2) model for the Euro Area's IPI growth rate.

	EURO AREA - 1993M2:2008M7			
	MSMH(2)-AR(1)	MSMH(2)-AR(2)	MSMH(2)-AR(3)	MSMH(2)-AR(4)
HQ criterion	-6.951	-6.9923	-6.9759	-6.9776

Table 4-14: Hannan Quinn criterion for Euro Area MSMH(2)-AR(p), IPI Data

The summary results shown in Table 4-15 are rather different from those of Table 4-4 regarding GDP. In fact, the first regime is now estimated as a regime of negative growth, with an estimate of an average annual rate of growth of -0.6%. This could be caused by the differences in the sample period, the structure of the model and the time series.

The model seems to have difficulties in capturing some of the stylized facts in the business cycle literature: first, both regimes tend to last approximately the same, which is in contradiction with the view that expansions last much longer than recessions; second, the standard deviations in both regimes are fairly identical, which also contradicts the literature on business cycles that state that there is increased volatility during recessions.

	MSMH(2)-AR(2) 1993M2:2008M7
regime dependent mean	
$\mu 1$	-0.0005
t-value	-0.6636
$\mu 2$	0.0038
t-value	6.4399
Ergodic Probability	
regime 1	0.4651
regime 2	0.5349
Duration	
regime 1	10.93
regime 2	12.57
Standard error σ	
regime 1	0.0063779
regime 2	0.0060419

Table 4-15: Summary results of a MSMH(2)-AR(2) for the Euro Area, 1993M2:2008M7, IP Data

The ergodic probabilities are similar because the transition probabilities p_{11} and p_{22} are quite similar – which means that the probability of continuing in an expansionary (recessionary) period if the previous period was also an expansionary (recessionary) one is practically the same (which in turn originates regimes which have almost the same duration). In contrast, one would have expected p_{21} to be much higher than p_{11}.

$$\hat{p}_{ij} = \begin{bmatrix} 0.9085 & 0.0915 \\ 0.0795 & 0.9205 \end{bmatrix}$$

The smoothed probabilities allow for the following chronology of regimes (which can also be seen in Table 7-15):

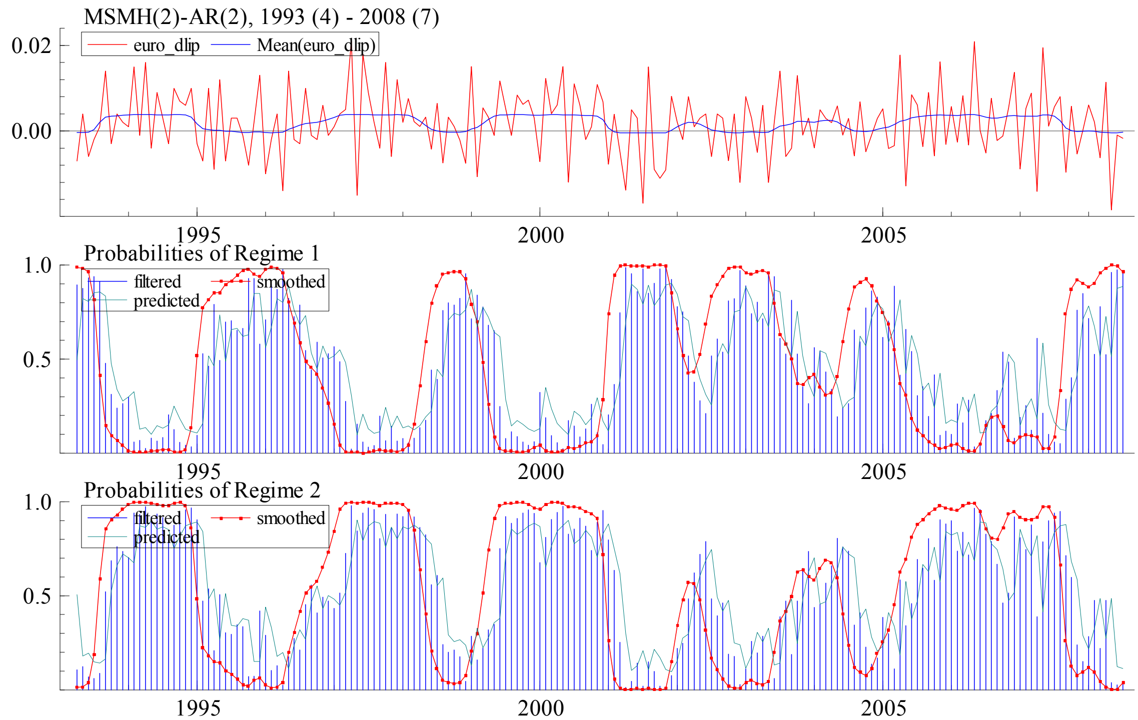

Figure 4-2: Euro Area regime chronology, IPI data

4.3.2.2 Individual countries - univariate approach

The Hannan Quinn criterion values obtained for each lag extension *p* for each country are as follows:

	1993M2:2008M7			
	MSMH(2)-AR(1)	MSMH(2)-AR(2)	MSMH(2)-AR(3)	MSMH(2)-AR(4)
Czech Republic	-4.5854	**[-4.6102]**	-4.5891	-4.5758
Hungary	-5.0031	-4.9987	**[-5.0076]**	-4.9916
Poland	-4.0101	**[-4.2938]**	-4.2518	-4.2268
Romania	-3.9508	**[-3.9582]**	-3.9404	-3.9351
Slovak Republic	-4.4336	**[-4.5246]**	-4.5066	-4.5189
Turkey	-3.453	**[-3.4825]**	-3.4802	-3.4562

Table 4-16: Hannan Quinn criterion for MSMH(2)-AR(p), IPI Data - Czech Republic, Hungary, Poland, Romania, Slovak Republic and Turkey

Note: the values in bold show the smallest Hannan Quinn criterion; the values in brackets show which model was chosen

With the only exception of Hungary, the criterion suggests fitting a MSMH(2)-AR(2) to every country. The estimates of the suggested models have generated the results in Table 4-17. Only in the cases of Poland, Romania and the Slovak Republic does the first regime represent a regime of average negative growth (recession), whereas for the others both regimes are characterized by positive growth rates that are smaller in the first regime.

Poland, Romania and the Slovak Republic have results consistent with the stylized fact that expansions last longer than recessions. However, Poland and Romania's business cycles volatility is twice as big during expansions as it is during recessions, which is in clear contradiction with the literature.

As regards the other countries, one common result across the cases of the Czech Republic, Hungary and Turkey is that the low growth regime lasts two to three times longer than the normal growth regime.

	Czech Republic MSMH(2)-AR(2)	Hungary MSMH(2)-AR(3)	Poland MSMH(2)-AR(2)	Romania MSMH(2)-AR(2)	Slovak Republic MSMH(2)-AR(2)	Turkey MSMH(2)-AR(2)
regime dependent mean						
μ1	0.0015	0.0023	-0.0017	-0.0073	-0.0032	0.0032
t-value	0.6591	1.2676	-1.3847	-1.1603	-0.5031	1.1067
μ2	0.0065	0.0177	0.0084	0.0045	0.0073	0.0052
t-value	2.1447	4.4449	7.1207	3.2469	2.7544	2.8452
Ergodic Probability						
regime 1	0.6215	0.7541	0.2387	0.2078	0.2698	0.6146
regime 2	0.3785	0.2459	0.7613	0.7922	0.7302	0.3854
Duration						
regime 1	5.43	6.47	8.57	12.12	2.73	6.16
regime 2	3.31	2.11	27.33	46.23	7.38	3.86
Standard error σ						
regime 1	0.026642	0.016764	0.014	0.053078	0.019697	0.051799
regime 2	0.013627	0.012266	0.028518	0.025207	0.023153	0.016718

Table 4-17: Summary results of a MSMH(2)-AR(p) for Czech Republic, Hungary, Poland, Romania, Slovak Republic and Turkey, 1993M2:2008M7, IPI Data

The regime chronologies are available from Figure 7-27 to Figure 7-32 or from Table 7-16 to Table 7-21.

4.3.2.3 Synchronization

Table 4-18 shows the general results regarding Pearson's contingency index. In stark contrast to the findings obtained with the GDP time series, this indicator now that suggests that Turkey is the country with the least degree of synchronization of its IPI BC with the cycle of the IPI of the Euro Area.

Similarly to what has been found with real GDP, Poland, Hungary and (albeit to a lesser extent) the Slovak Republic form a group of countries which IPI's cycles are rather synchronized with the Euro Area's IPI cycle. The Czech Republic appears not to be as synchronized with the Euro Area as it was in the case of real GDP.

It is also interesting to notice that the synchronization levels between the CEECs IPI's cycles tends to be smaller than the levels previously computed with the real GDP.

	Czech Rep	Hungary	Poland	Romania	Slovak Rep	Turkey	Euro Area
Czech Rep	100						
Hungary	0.81458701	100					
Poland	9.32588992	20.945634	100				
Romania	10.3337999	10.424875	2.6879957	100			
Slovak Rep	21.2598725	9.9608718	27.718162	17.186513	100		
Turkey	10.278787	1.4317498	1.6546299	16.099266	12.598522	100	
Euro Area	21.3605645	46.182275	47.21649	12.04415	33.492113	4.7219177	100

Table 4-18: Pearson's corrected contingency coefficient, IPI data

Turning now to the main characteristics of the IPI's business cycles, table 4-19 shows the main results. The three countries for which it was found that the first regime consisted of a recessionary period in Table 4-17 are the ones showing a negative amplitude from peak to trough. In the case of the Euro Area, the results in Table 4-19 are consistent with those in Table 4-15.

It is noteworthy that Poland and Romania feature the largest welfare gains during expansions. In turn, the Slovak Republic and the Euro Area – which face recessionary regimes, differently from the other countries – have relatively small values for CM_{TP}. Although the trough-to-peak steepness measure is similar between the Euro Area and Romania, the latter's expansionary period has a much bigger duration and amplitude.

	Dpt	Dtp	AMPpt	AMPtp	STEEPpt	STEEPtp	CMpt	CMtp
Czech	7.6875	3.5882	0.0145	0.0252	0.0019	0.0070	0.0558	0.0451
Hungary	11.3077	2.7692	0.0292	0.0548	0.0026	0.0198	0.1650	0.0759
Poland	11	35	-0.0149	0.2955	-0.0014	0.0084	-0.0818	5.1721
Romania	11.6667	49.6667	-0.1008	0.2236	-0.0086	0.0045	-0.5881	5.5523
Slovak	3.875	21.8571	-0.0268	0.1500	-0.0069	0.0069	-0.0519	1.6392
Turkey	8.5385	6.0833	0.0066	0.0471	0.0008	0.0077	0.0281	0.1432
Euro	14.1667	16.5	-0.0129	0.0692	-0.0009	0.0042	-0.0912	0.5712

Table 4-19: Business cycles' characteristics, IPI Data

Following Altavilla (2004), Figure 4-3 graphically compares the main characteristics of the synthetic average cycle for the Euro Area (dashed line), with those of Poland, Slovak Republic and Romania. The y-axis represents the average amplitude of recession (negative values) and expansion (positive values); the x-axis measures the expected duration of recession (negative values) and expansion (positive values).

The differences are quite marked, especially during expansions – when the asymmetry is more evident both in terms of duration and amplitude, which are smaller for the Euro Area. Apart from that, the Slovak Republic, Poland and Romania seem to share some similarity with the Euro Area during contractionary periods. Whereas Romania's steepness is in line with that of the Euro Area, Poland registers a steepness value that is twice as big as the Euro Area's.

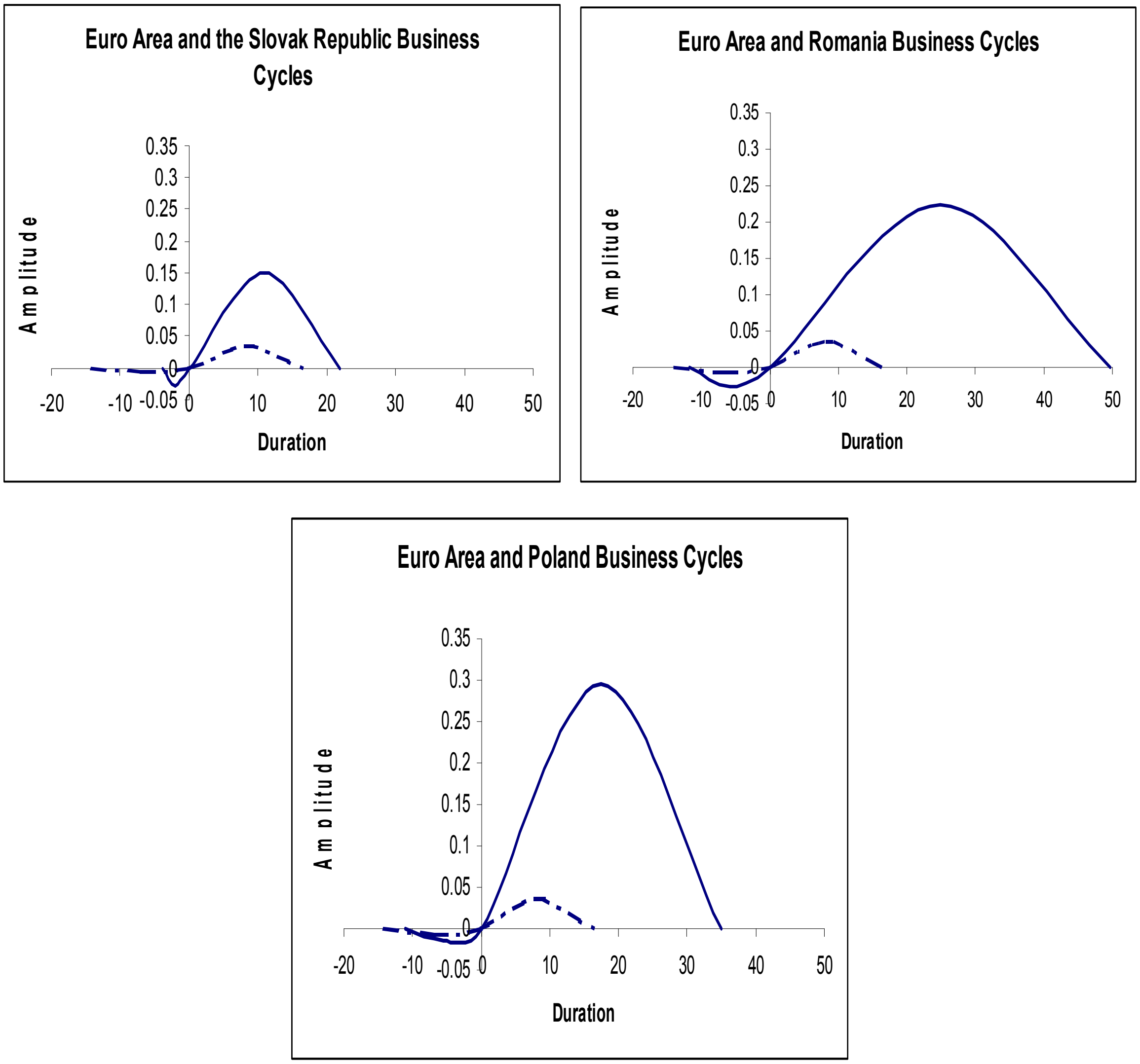

Figure 4-3: Comparison between Business Cycles, IPI Data
Note: Dashed line refers to the Euro Area Business Cycle

We now turn to the *concordance* index.

The *concordance* index and its mean corrected counterpart yield approximately the same ranking that has been previously obtained with the real GDP data. In fact, Poland, the Slovak Republic and Hungary emerge as the most synchronized countries with the Euro Area. Interestingly, the null of independence with the Euro Area's IPI business cycle is rejected for all these countries, thus clearly allowing for a conclusion that their IPI's cycles are dependent of the Euro Area's.

In sharp contrast to these results are those for Turkey and Romania, for which the null of independence of their IPI business cycles with that of the Euro Area's IPI cycle can not be rejected. The *p*-value of the test is, for the case of the Czech Republic, relatively smaller than the values for Turkey and Romania, but nevertheless the null can not be rejected at conventional significance levels.

	Czech	Hungary	Poland	Romania	Slovak	Turkey
Concordance Index	0.557377	0.6120219	0.6721311	0.4918033	0.6174863	0.4754098
Mean corrected CI	0.0714862	0.1368808	0.1508555	-0.033504	0.08994	-0.016304
Standardized Concordance Index	1.468292	5.08212	3.253116	-0.631094	2.499187	-0.291695
p-value	0.1438	0	0.0014	0.5288	0.0133	0.7709

Table 4-20: *Concordance* Index with the Euro Area, IPI Data

4.3.2.4 Synchronization with the Euro Area Core – multivariate approach

Once again replicating the analysis made with the time series of real GDP, we estimate a multivariate MS regime model for the core countries of the EMU and use its estimates as a robustness check for the results obtained with aggregate Euro Area data.

We have estimated a MSMH(2)-VAR(2) model for Austria, Belgium, France, Germany and the Netherlands, according to the information criterion in next table.

	EURO AREA Core - 1993M2:2008M7			
	MSMH(2)-VAR(1)	MSMH(2)-VAR(2)	MSMH(2)-VAR(3)	MSMH(2)-VAR(4)
HQ criterion	-27.5466	-27.5603	-27.3695	-27.1056

Table 4-21: Hannan Quinn criterion for Euro Area Core MSMH(2)-VAR(p), IPI Data

Table 4-22 summarizes the main results for the chosen model.

MSMH(2)-VAR(2)
1993M2:2008M7

	Austria	Belgium	France	Germany	Netherlands
regime dependent mean					
μ1	0.001528	0.000901	-0.000101	-0.000565	-0.001742
t-value	1.1194	0.5561	-0.1542	-0.7198	-1.2138
μ2	0.005923	0.002946	0.002518	0.004288	0.004315
t-value	5.2643	1.94	2.9664	5.2065	2.9463
Ergodic Probability					
regime 1	0.4945				
regime 2	0.5055				
Duration					
regime 1	6.26				
regime 2	6.4				
Standard error σ					
regime 1	0.018891	0.023488	0.007975	0.010459	0.019423
regime 2	0.011628	0.017726	0.010285	0.00916	0.014618

Table 4-22: Summary results of a MSMH(2)-VAR(2) for the Euro Area Core, 1993M2:2008M7, IPI Data

We now compute the synchronization indicators and statistics using the results from this model as proxy for the Euro Area's core.

As regards the standardized *concordance* index, the main conclusion seems to be that while Hungary, Poland and the Slovak Republic maintain results suggesting high synchronization with the Euro Area Core, as well as seen for the Euro Area, the Czech Republic tends to be synchronized with the Core (although it didn't seem to synchronize with the Euro Area as a whole).

	Czech	Hungary	Poland	Romania	Slovak	Turkey
Concordance Index	0.5846995	0.6065574	0.6120219	0.4535519	0.5901639	0.5245902
Mean corrected CI	0.0894025	0.1148437	0.10493	-0.054884	0.0809818	0.0273523
Standardized Concordance Index	2.036763	3.561875	2.367086	-1.176234	2.513312	0.752952
p-value	0.0431	0.0005	0.019	0.241	0.0128	0.4525

Table 4-23: *Concordance* Index with the Euro Area Core, IPI Data

4.3.2.5 Discussion

Similarly to section 4.3.1.5, we have adapted and extended the literature surveys in Fidrmuc and Korhonen (2003a, 2006) in order to discuss our results in the light of the literature. Table 4-24 summarizes the bulk of the papers they surveyed, this time round those that have used IPI time series; the first row in the table shows the main findings of our own.

In a nutshell, our results show that Poland, Hungary and the Slovak Republic exhibit the highest concordance of their BCs with the BC of the Euro Area, using both the *contingency* and *concordance* index. When considering the core of the Euro Area, the Czech Republic also becomes synchronized with that group of countries.

The results in the literature that are more directly comparable to our results of sections 4.3.2.1 through 4.3.2.4 are Artis *et. al*'s (2004b), who perform the same sort of analysis but based on a non parametric way of determining the turning points, i.e., the Bry and Boschan algorithm. They have dismissed synchronization between the Euro Area BC and the cycle of the Slovak Republic, unlike our conclusions. However, when they consider Germany as proxy for the core Euro Area, instead of the aggregate Euro Area itself, they found an increase in the degree of synchronization of the Czech Republic's cycle with the Area's cycle – a result that is also present in this dissertation.

This dissertation's results are, to some degree, consistent with the literature's main findings' shown in Table 4-24. Similarly to us, Fidrmuc (2001) and Korhonen (2003) also consider Hungary to be the country with the most synchronized cycle to the EMU's – and remember that the *p*-values in our synchronization tests for Hungary are close to zero. Savva *et. al (*2007) have found that Hungary is the second most synchronized country, after Lithuania; as Lithuania is not part of the sample countries that we study, this ranking could not be compared to our results.

Study, year of publication	Methodoly and variables	Acceding countries	Comparison country/area	Period analyzed	Conclusions
Present dissertation	Analysis is based on various characteristics (including concordance index) of IPI's classical cycle determined by Markov Switching model	CZE, HU, PL, ROM, SL, TRK	Euro area and euro area core	M2:1993-M7:2008	HU, PL and SL's Business Cycle is proved to be synchronized with the Euro Area and its core, whereas CZE is synchronized with the core of the Euro Area.
Boone and Maurel (1998)	Correlation of detrended industrial production and unemployment	BLG, CZE, HU, PL, ROM, SL, SI	EU and DE	M1:1990-M11:1997	Relatively high degree of business cycle correlation for the acceding countries: higher than for Portugal and Greece.
Fidrmuc (2001)	Correlation of detrended industrial production (endogeneity)	CZE, HU, PL, SL, SI	DE	M1:1991/3-M12:1999	Business cycle, defined as IPI, strongly correlates with the German Cycle in Hungary and SI, and PL to a lesser extent.
Korhonen (2003)	Correlation of VAR impulse functions, industrial production	CZE, EST, HU, LV, LT, PL, ROM, SL, SI	Euro area	M1:1992/3/5-M12:2000	Some of the most advanced CEECs (especially Hu) exhibit a high level of correlation with the euro are business cycle
Artis *et. al* (2004b)	Correlation of yearly growth rates and standardized concordance index	CZE, SL, PL, HU, SL, EST, LV, LT	DE, AUST, IT, EURO ZONE	CZE (M1:1990-M12:2002), SL (M1:1993-M12:2002), PL (M1:1985-M12:2002), HU (M1:1980-M12:2002), SI (M1:1980-M12:2002), EST (M1:1995-M12:2002), LV (M1:1980-M12:2002), LT (M1:1996-M11:2002)	HU and PL have significant concordande with one or more countries of the eurozone and the euro area itself
Boreiko (2003)	Fuzzy clustering analysis	BUL, CZE, EST, HUN, LV, LT, PL, ROM, SL, SI, CRO	EU12, DE	1993-2001	EST and SI are leaders both in nominal and real convergence
Savva *et. al* (2007)	bivariate VAR-GARCH specification with a smoothly time-varying transition correlation that allows for structural change	CY, CZE, EST, HUN, LT, PL, ROM, SL, SI, CRO, FYROM, TRK	Euro Zone	earliest available data to June 2006	All countries have experienced an increased synchronization with the euro area (being bigger in LT and HUN), remaining quite low for FYROM and TRK

Table 4-24: Survey regarding the synchronization of CEECs with the Euro Area using IPI data

Note: Adaptation of the survey presented in Fidrmuc and Korhonen (2003a, 2006)

5 Conclusions

This dissertation has assessed the synchronization between the business cycles (BCs) of central and eastern European countries (CEECs) and the BC of the Euro Area. We have focused on CEECs that have adhered to the European Union (EU) but do not yet participate in the European Monetary Union (EMU), but have also extended the analysis to some countries that are still in a phase of candidacy to EU membership.

The purpose of the analysis has been to quantitatively evaluate whether these countries are well prepared for integrating the EMU, considering one of the pre-conditions for a successful integration into a monetary union suggested in the theory of the optimal currency areas (OCA) that is not present in the European Union Treaty criteria (generally known as Maastricht criteria).

We have adopted an approach to the identification of business cycles that has become known as the *classical cycle*. After reviewing the alternatives for establishing the chronology of BCs within the *classical cycle* approach, we have chosen a parametric method for estimating BCs' turning points, namely the Markov Switching (MS) regime models.

We firstly established the BCs turning points and chronology for the considered CEECs and the Euro Area, on the basis of univariate MS-regime models and the resulting dichotomic variable S_t containing information about expansionary and recessionary periods. Then, we submitted the estimated BCs to a battery of synchronization indicators and tests. We have used indicators and tests suggested by or in the spirit of Harding and Pagan. Specifically, we computed *contingency* indexes, *concordance* indexes, the main BCs' characteristics (such as amplitude, duration and steepness), and a statistical test based on the *standardized concordance* index.

We have performed two basic sensitivity checks of our results.
First, in order to evaluate the eventual disparity in results commonly attributed to the use of different data sets, we have thoroughly conducted our analysis sequentially with two time-series that represent aggregate real economic activity – real gross domestic product (GDP) and the industrial production index (IPI).
Second, in order to evaluate the sensitivity of the results to the present composition of the Euro Area, we have assessed synchronization between the BCs of the considered CEECs and that of the core of the Euro Area, estimated via a multivariate MS-regime model for a group of EMU countries including Austria, Belgium, France, Germany and Netherlands.

For each dataset, the main results were the following.
Regarding the real GDP data, the *contingency* and the *concordance* index return similar results: using the former, Turkey seems to be the country with most synchronized BC *vis-à-vis* the Euro Area and an intermediate level of correlation is achieved by the Czech Republic, followed by Hungary, Poland and the Slovak Republic; using the mean corrected version of the latter, Turkey, followed by the Czech Republic, show the highest levels of synchronization with the Euro Area.

However, the standardized *concordance* index, for a significance level of 5%, doesn't reject the null hypothesis of independence between the Czech Republic's BC and the Euro Area BC, a result that only occurs for Turkey and Hungary. Analyzing the concordance of the CEECs with the core of the Euro Area provided different results: Poland and the Slovak Republic are the most concordant – which is consistent with Boone and Maurel (1999).

This analysis was complemented with information regarding the shape of the BC, as synchronization is a necessary but not sufficient condition to determine if countries would face low costs when entering a currency area [see Camacho *et al.* (2008, page 2166)]. The results for the Euro Area signal a more stable behaviour of the BC, with its welfare changes being much smaller when compared to the other countries – a natural feature of larger areas,. Whereas there are countries such as Hungary, Poland and the Czech Republic that share some similar characteristics between themselves, it is difficult to encounter countries whose BC's shape is similar in most aspects to that of the Euro Area.

Using IPI data, the results are homogenous when using the *contingency* and *concordance* index and even the standardized *concordance* index: for all these indicators, Poland, Hungary and the Slovak Republic exhibit the highest concordance of their BCs with the BC of the Euro Area. When considering the core of the Euro Area, the Czech Republic becomes synchronized with that group of countries. This result for the degree of synchronization of the Czech Republic *vis-à-vis* the core of the Euro Area reproduces the findings in Artis *et. al*'s (2004b).

We have not found many similarities between the Euro Area and the CEECs's BCs' characteristics using IPI data. This is especially clear in Figure 4-3. The differences are significant, especially during expansions when the asymmetry is more evident both in terms of duration and amplitude, which are smaller for the Euro Area. In addition to the Slovak Republic, only Poland and Romania seem to share some similarity with the Euro Area during contractionary periods.

In sum, our results confirm the disparity between analysis using different data sets, that we have found in our literature review.

Overall, it is hard to determine whether there is a group of CEECs with BCs clearly synchronized and with similar characteristics with the cycle of the EMU. Yet, it should be kept in mind that some authors would stress the endogeneity view of the OCA theory, which argues that synchronization is reinforced through participation in the currency union. Against this background, the question is more whether BCs are very far from synchronization and similarity than whether they are already synchronized and similar. Tentatively, one could argue that among the studied countries, Hungary and Poland seem to be the ones with BCs more closely to synchronization and similarity to the BC of the Euro Area.

This dissertation is evidently limited because of data scarcity. Our analysis focuses on little more than a decade of data, and covers a period that has been characterized by low volatility. The use of the IPI adds data-points and degrees of freedom to the estimation, but obviously does not add to the essential information on the actual business cycles of the covered period. Once more data is available, and with the advantage of covering the current international crisis – in which overall volatility is increasing – then the empirical analysis should be far more informative. On one hand, we would have found different business cycles chronologies even with the very same methods. On the other hand, we would be able to employ more sophisticated models.

As regards eventual developments of our research, in addition to waiting for more data, the use of any of a variety of recently emerging methods could prove useful in assessing the issue that we've chosen to study in this dissertation. For example, using the dynamic factor models, or exploring the recent developments of MS-regimes that we've reviewed in chapter 3, especially in multivariate contexts, should be fruitful avenues for future research.

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7 Annex

7.1 GDP

7.1.1 Data

Units	Scale	Country	Database	Series code	Descriptor	Sample period From:	To:
National Currency	Millions	Bulgaria	IFS	91899B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1994q1	2008q1
Index number	Units	Bulgaria	IFS	91899BIPZF...	GDP DEFLATOR (2000=100)	2002q1	2008q1
National Currency	Millions	Croatia	IFS	96099B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1997q1	2008q1
Index number	Units	Croatia	IFS	96099BIPZF...	GDP DEFLATOR (2000=100)	1997q1	2008q1
National Currency	Billions	Czech Republic	IFS	93599B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1990q1	2008q1
Index number	Units	Czech Republic	IFS	93599BIPZF...	GDP DEFLATOR (2000=100)	1994q1	2008q1
National Currency	Millions	Estonia	IFS	93999B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1993q1	2008q1
Index number	Units	Estonia	IFS	93999BIPZF...	GDP DEFLATOR (2000=100)	1993q1	2008q1
Index number	Units	Hungary	IFS	94499BIPZF...	GDP DEFLATOR (2000=100)	1995q1	2008q1
National Currency	Billions	Hungary	IFS	94499B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1995q1	2008q1
National Currency	Millions	Latvia	IFS	94199B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1990q1	2008q1
Index number	Units	Latvia	IFS	94199BIPZF...	GDP DEFLATOR (2000=100)	1990q1	2008q1
National Currency	Millions	Lithuania	IFS	94699B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1993q1	2008q1
Index number	Units	Lithuania	IFS	94699BIPZF...	GDP DEFLATOR (2000=100)	1993q1	2008q1
National Currency	Millions	Poland	IFS	96499B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1995q1	2008q1
Index number	Units	Poland	IFS	96499BIPZF...	GDP DEFLATOR 2000=100	1995q1	2008q1
National Currency	Millions	Romania	IFS	96899B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1997q1	2007q3
Index number	Units	Romania	IFS	96899BIPZF...	GDP DEFLATOR (2000=100)	1998q1	2007q3
National Currency	Millions	Slovak Republic	IFS	93699B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1993q1	2008q1
Index number	Units	Slovak Republic	IFS	93699BIPZF...	GDP DEFLATOR (2000=100)	1993q1	2008q1
National Currency	Millions	Turkey	IFS	18699B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1987q1	2007q4
Index number	Units	Turkey	IFS	18699BIPZF...	GDP DEFLATOR (2000=100)	1987q1	2007q4
National Currency	Billions	Austria	IFS	12299B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1985q1	2008q1
Index number	Units	Austria	IFS	12299BIPZF...	GDP DEFLATOR (2000=100)	1985q1	2008q1
Index number	Units	Belgium	IFS	12499BIPZF...	GDP DEFLATOR (2000=100)	1985q1	2008q1
National Currency	Billions	Belgium	IFS	12499B..ZF...	GROSS DOMESTIC PRODUCT (GDP)	1985q1	2008q1
National Currency	Billions	France	IFS	13299B.CZF...	GROSS DOMESTIC PRODUCT SA	1985q1	2008q1
Index number	Units	France	IFS	13299BIRZF...	GDP DEFLATOR (2000=100)	1985q1	2008q1
Index number	Units	Germany	IFS	13499BIRZF...	GDP DEFLATOR (2000=100)	1985q1	2008q1
National Currency	Billions	Germany	IFS	13499B.CZF...	GROSS DOMESTIC PRODUCT SA	1985q1	2008q1
National Currency	Billions	Netherlands	IFS	13899B.CZF...	GROSS DOMESTIC PRODUCT SA	1985q1	2008q1
Index number	Units	Netherlands	IFS	13899BIRZF...	GDP DEFLATOR (2000=100)	1985q1	2008q1

Table 7-1: GDP variables' codes and time span

		LN (Yt)				First Difference: LN (Yt) - LN (Yt-1)			
		Constant	Stationery	Constant and Trend	Stationery	Constant	Stationery	Constant and Trend	Stationery
Czech Republic	p-value ADF test	1	X	0.9995	X	0.0715	✓	0	✓
	Constant t-statistic	-2.475478		-0.661953		2.069885		0.434497	
	Trend t-statistic			0.385373				2.747214	
Estonia	p-value ADF test	0.993	X	0.345	X	0.0001	✓	0.0047	✓
	Constant t-statistic	-0.34275		2.493243		3.998348		3.319295	
	Trend t-statistic			2.534233				2.0246	
Hungary	p-value ADF test	0.9406	X	0.5754	X	0	✓	0	✓
	Constant t-statistic	0.499096		2.061004		5.424864		3.848491	
	Trend t-statistic			2.018978				-0.498163	
Latvia	p-value ADF test	1	X	0.8741	X	0.0025	✓	0	✓
	Constant t-statistic	-1.875621		1.418009		3.78776		2.636485	
	Trend t-statistic			1.803146				2.7767	
Lithuania	p-value ADF test	0.9887	X	0.8142	X	0	✓	0	✓
	Constant t-statistic	-0.30494		1.547533		5.654817		2.485166	
	Trend t-statistic			1.624276				1.346029	
Poland	p-value ADF test	0.8349	X	0.2074	X	0	✓	0	✓
	Constant t-statistic	0.819194		2.811212		5.46401		3.209476	
	Trend t-statistic			2.705019				-0.262868	
Slovak Republic	p-value ADF test	1	X	1	X	0.4515	X	0	✓
	Constant t-statistic	-2.643692		-1.59486		1.661215		1.675205	
	Trend t-statistic			-1.005871				2.458819	
Turkey	p-value ADF test	0.6247	X	0.2035	X	0	✓	0	✓
	Constant t-statistic	1.408305		2.850017		2.686582		1.903506	
	Trend t-statistic			2.443566				-0.687314	
Euro Area	p-value ADF test	0.8295	X	0.7036	X	0.0033	✓	0.017	✓
	Constant t-statistic	0.76511		1.777029		3.430251		2.77995	
	Trend t-statistic			1.678818				-0.474478	
Austria	p-value ADF test	0.9666	X	0.5602	X	0	✓	0.0000	✓
	Constant t-statistic	0.075888		2.08136		5.132824		2.618666	
	Trend t-statistic			2.094049				0.384134	
Belgium	p-value ADF test	0.9355	X	0.3775	X	0.0000	✓	0	✓
	Constant t-statistic	0.294112		2.413458		4.808428		2.267684	
	Trend t-statistic			2.394042				0.150513	
France	p-value ADF test	0.8945	X	0.912	X	0.0000	✓	0.0001	✓
	Constant t-statistic	0.665845		1.177054		4.463904		3.057132	
	Trend t-statistic			1.085058				-0.265895	
Germany	p-value ADF test	0.9522	X	0.8163	X	0	✓	0	✓
	Constant t-statistic	0.113272		1.521913		3.499865		1.633158	
	Trend t-statistic			1.545849				0.366777	

Table 7-2: ADF stationarity tests performed to the log of real GDP data

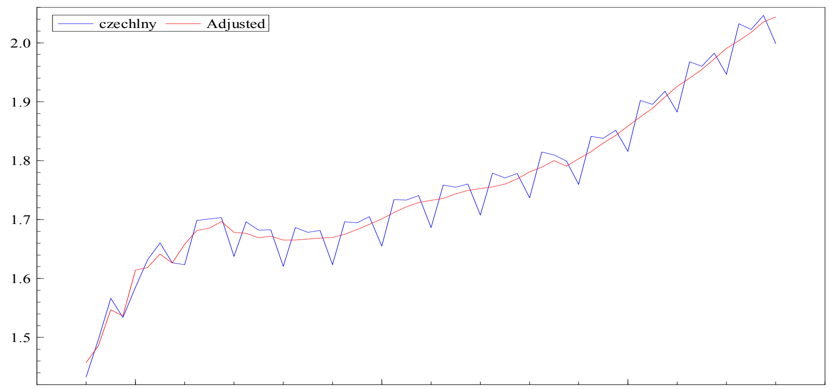

Figure 7-1: Comparison between seasonally and not seasonally adjusted log GDP for Czech Republic

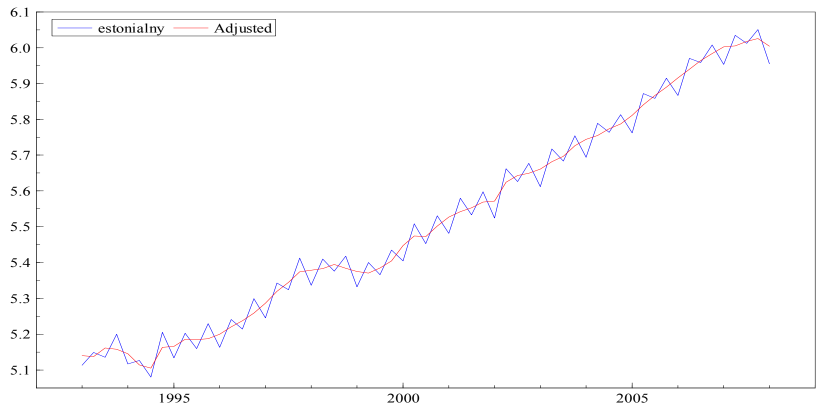

Figure 7-2: Comparison between seasonally and not seasonally adjusted log GDP for Estonia

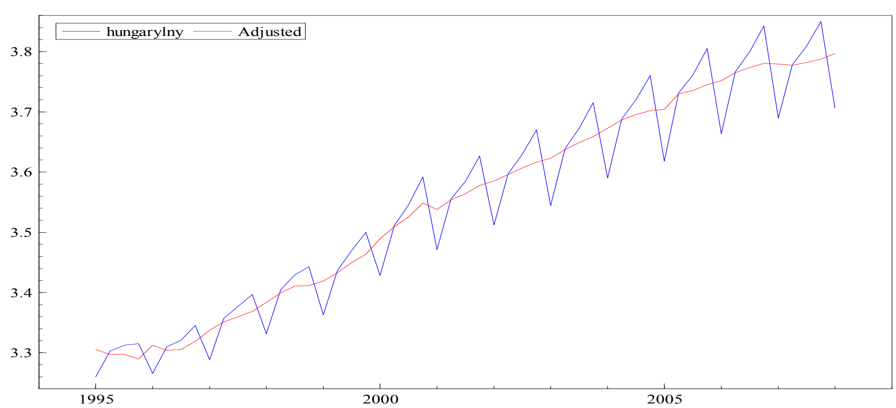

Figure 7-3: Comparison between seasonally and not seasonally adjusted log GDP for Hungary

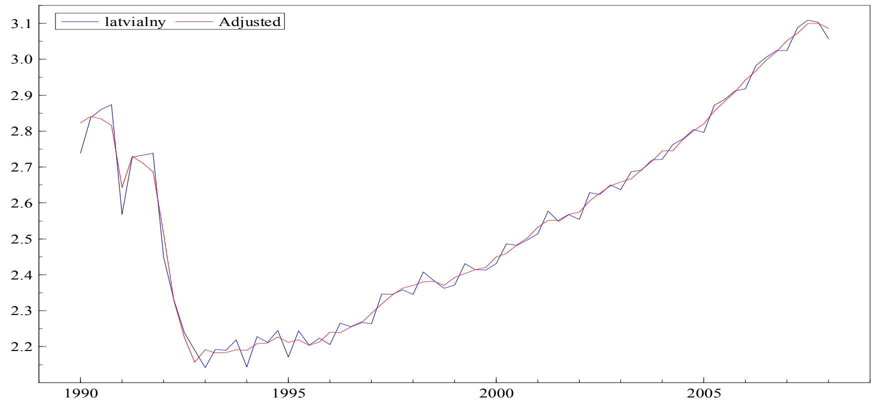

Figure 7-4: Comparison between seasonally and not seasonally adjusted log GDP for Latvia

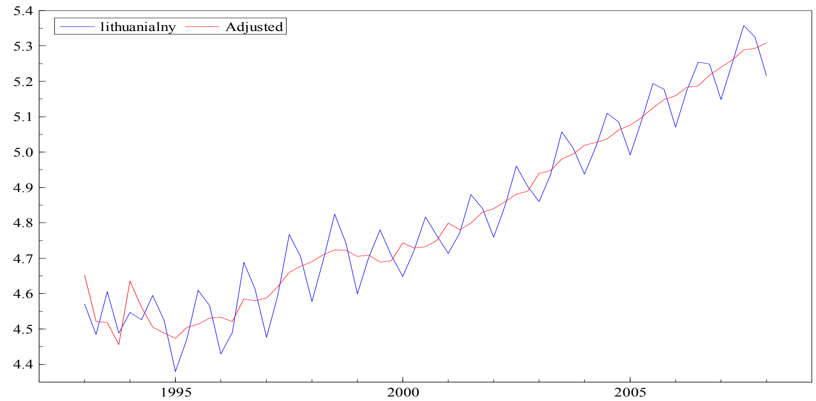

Figure 7-5: Comparison between seasonally and not seasonally adjusted log GDP for Lithuania

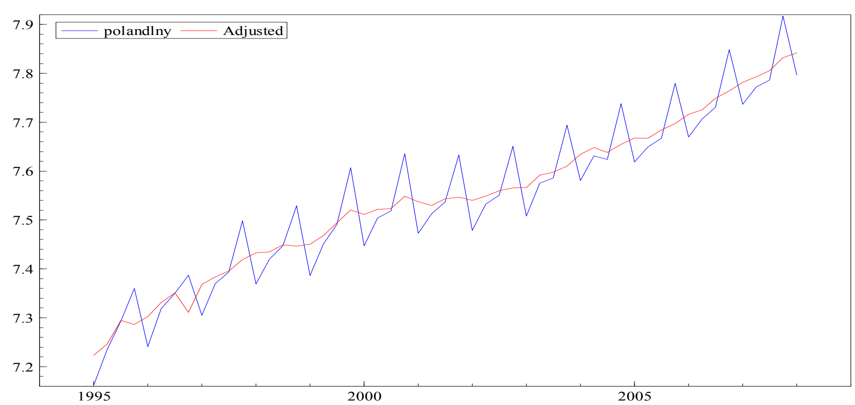

Figure 7-6: Comparison between seasonally and not seasonally adjusted log GDP for Poland

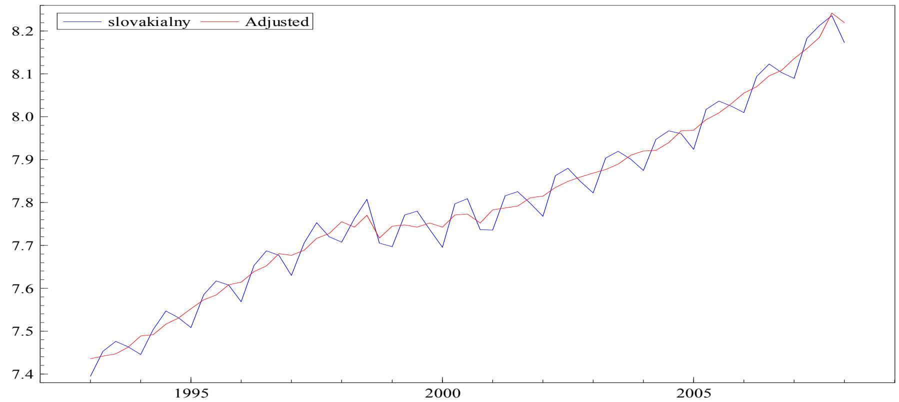

Figure 7-7: Comparison between seasonally and not seasonally adjusted log GDP for Slovakia

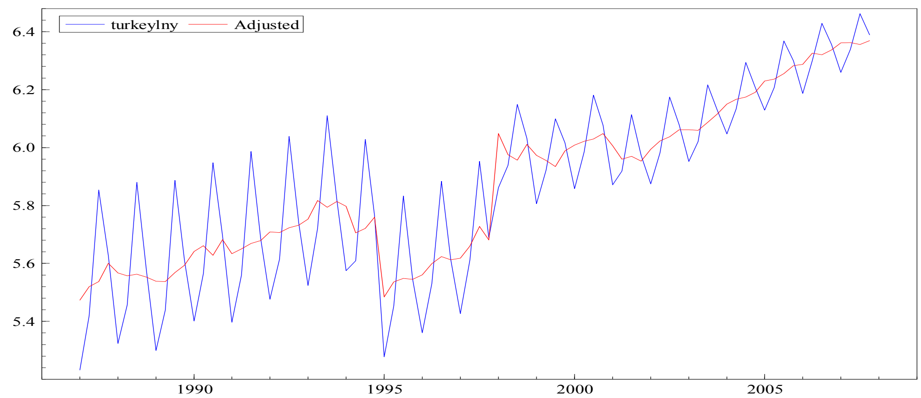

Figure 7-8: Comparison between seasonally and not seasonally adjusted log GDP for Turkey

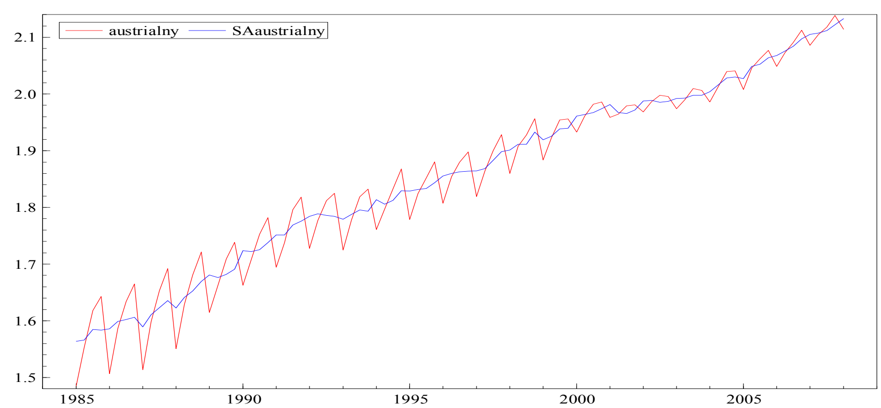

Figure 7-9: Comparison between seasonally and not seasonally adjusted log GDP for Austria

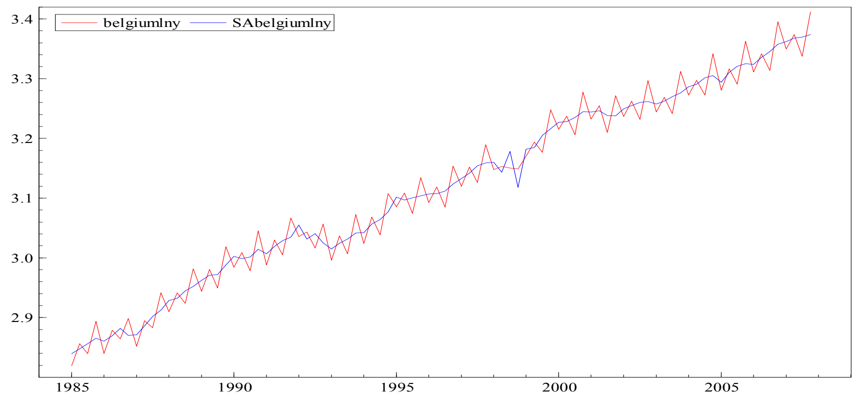

Figure 7-10: Comparison between seasonally and not seasonally adjusted log GDP for Belgium

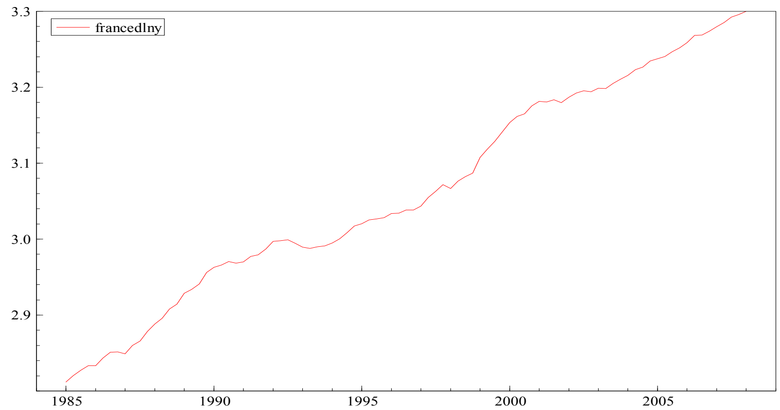

Figure 7-11: log GDP for France

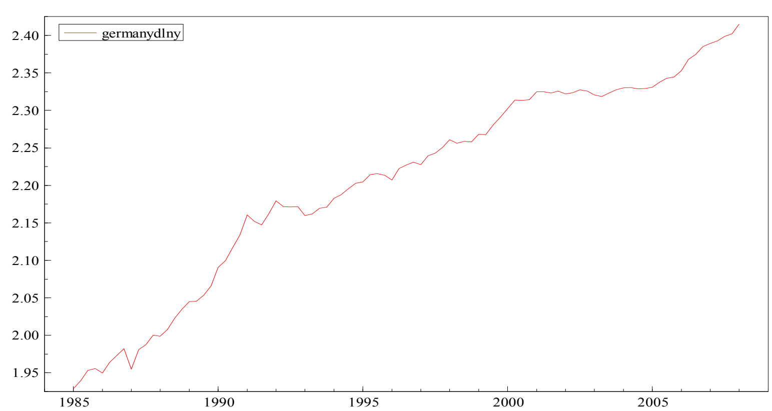

Figure 7-12: log GDP for Germany

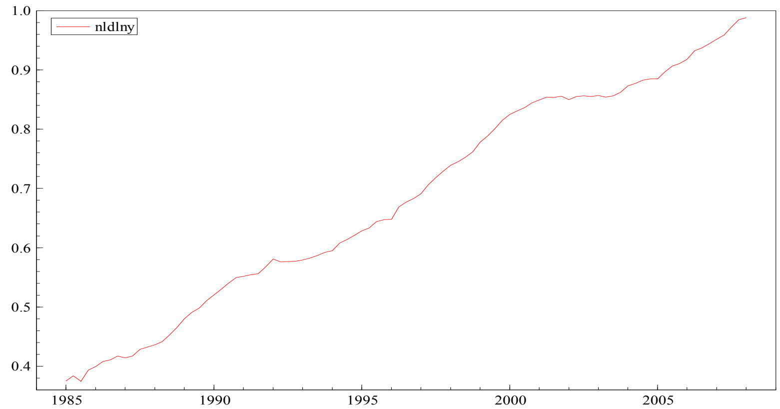

Figure 7-13: log GDP for the Netherlands

7.1.2 MS Regimes

MSM(2)-AR(3) model of euroareadlny
Estimation sample: 1996 (1) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1996:1 - 1996:1 [0.9998]	1996:2 - 1996:3 [0.9996]
1996:4 - 1997:1 [1.0000]	1997:2 - 1997:2 [1.0000]
1997:3 - 1997:3 [0.9999]	1997:4 - 1998:3 [0.9955]
1998:4 - 1998:4 [0.9999]	1999:1 - 1999:1 [1.0000]
1999:2 - 1999:2 [1.0000]	1999:3 - 2000:2 [1.0000]
2000:3 - 2000:3 [1.0000]	2000:4 - 2001:1 [1.0000]
2001:2 - 2003:2 [0.9067]	2003:3 - 2005:3 [0.9484]
2005:4 - 2005:4 [0.9293]	2006:1 - 2006:2 [0.9949]
2006:3 - 2006:3 [0.9920]	2006:4 - 2007:1 [0.9971]
2007:2 - 2007:2 [0.9893]	2007:3 - 2007:3 [0.9739]
2007:4 - 2007:4 [0.5654]	

Table 7-3: Regime chronology for the MSM(2)-AR(3) model of the Euro Area, GDP Data. Smoothed probabilities in brackets

CZECH
MSM(2)-AR(2)
Estimation sample: 1995 (4) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1995:4 - 1995:4 [1.0000]	1996:1 - 1996:2 [0.9999]
1996:3 - 2003:4 [0.9722]	2004:1 - 2007:4 [0.9761]

Table 7-4: Regime chronology for the MSM(2)-AR(2) model of the Czech Republic, GDP Data. Smoothed probabilities in brackets

ESTONIA
MSM(2)-AR(1)
Estimation sample: 1995 (3) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1995:3 - 1995:4 [0.7890]	1996:1 - 1997:4 [0.9523]
1998:1 - 1999:2 [0.8161]	1999:3 - 2007:4 [0.9608]

Table 7-5: Regime chronology for the MSM(2)-AR(1) model of Estonia, GDP Data. Smoothed probabilities in brackets

HUNGARY
MSM(2)-AR(4)
Estimation sample: 1996 (2) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1996:2 - 1996:3 [0.9961]	1996:4 - 2000:4 [0.9998]
2001:1 - 2001:1 [0.9998]	2001:2 - 2007:4 [0.9999]

Table 7-6: Regime chronology for the MSM(2)-AR(4) model of Hungary, GDP Data. Smoothed probabilities in brackets

LATVIA
MSM(2)-AR(2)
Estimation sample: 1995 (4) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1995:4 - 1995:4 [0.9983]	1996:1 - 1996:1 [0.9776]
1996:2 - 1996:4 [0.8203]	1997:1 - 1997:4 [0.9857]
1998:1 - 1998:4 [0.9987]	1999:1 - 1999:1 [0.9656]
1999:2 - 1999:4 [0.9833]	2000:1 - 2000:1 [0.9999]
2000:2 - 2000:2 [0.9566]	2000:3 - 2001:2 [0.9404]
2001:3 - 2002:1 [0.8667]	2002:2 - 2002:4 [0.9955]
2003:1 - 2003:2 [0.9809]	2003:3 - 2004:1 [0.9993]
2004:2 - 2004:2 [0.9999]	2004:3 - 2007:3 [0.9984]
2007:4 - 2007:4 [0.9999]	

Table 7-7: Regime chronology for the MSM(2)-AR(2) model of Latvia, GDP Data. Smoothed probabilities in brackets

LITHUANIA
MSM(2)-AR(2)
Estimation sample: 1995 (4) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1998:4 - 1999:3 [0.9646]	1995:4 - 1998:3 [0.9634]
	1999:4 - 2007:4 [0.9806]

Table 7-8: Regime chronology for the MSM(2)-AR(2) model of Lithuania, GDP Data. Smoothed probabilities in brackets

POLAND
MSM(2)-AR(2)
Estimation sample: 1995 (4) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1996:4 - 1996:4 [0.9322]	1995:4 - 1996:3 [0.8493]
1998:2 - 1999:1 [0.8507]	1997:1 - 1998:1 [0.9555]
2000:1 - 2003:1 [0.9329]	1999:2 - 1999:4 [0.9669]
2004:3 - 2005:2 [0.8244]	2003:2 - 2004:2 [0.7985]
	2005:3 - 2007:4 [0.9178]

Table 7-9: Regime chronology for the MSM(2)-AR(2) model of Poland, GDP Data. Smoothed probabilities in brackets

SLOVAKIA
MSM(2)-AR(1)
Estimation sample: 1995 (3) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1997:1 - 2004:2 [0.8803]	1995:3 - 1996:4 [0.6411]
	2004:3 - 2007:4 [0.9052]

Table 7-10: Regime chronology for the MSM(2)-AR(1) model of the Slovak Republic, GDP Data. Smoothed probabilities in brackets

TURKEY
MSM(2)-AR(1)
Estimation sample: 1995 (3) - 2007 (4)

Regime 1 = 1	Regime 2 = 0
1995:3 - 1996:1 [0.5041]	1996:2 - 1996:2 [0.5021]
1996:3 - 1996:4 [0.5020]	1997:1 - 1998:3 [0.5327]
1998:4 - 2003:3 [0.5144]	2003:4 - 2004:2 [0.5036]
2004:3 - 2004:3 [0.5015]	2004:4 - 2005:1 [0.5015]
2005:2 - 2007:4 [0.5058]	

Table 7-11: Regime chronology for the MSM(2)-AR(1) model of Turkey, GDP Data. Smoothed probabilities in brackets

Regime 1 = 1	Regime 2 = 0
1995:3 - 1996:1 [0.9932]	1996:2 - 1998:1 [0.9880]
1998:2 - 1998:4 [0.9852]	1999:1 - 2000:2 [0.9412]
2000:3 - 2005:1 [0.9731]	2005:2 - 2007:4 [0.9348]

Table 7-12: Regime chronology for the MSM(2)-VAR(1) model of Euro Area Core, GDP Data. Smoothed probabilities in brackets

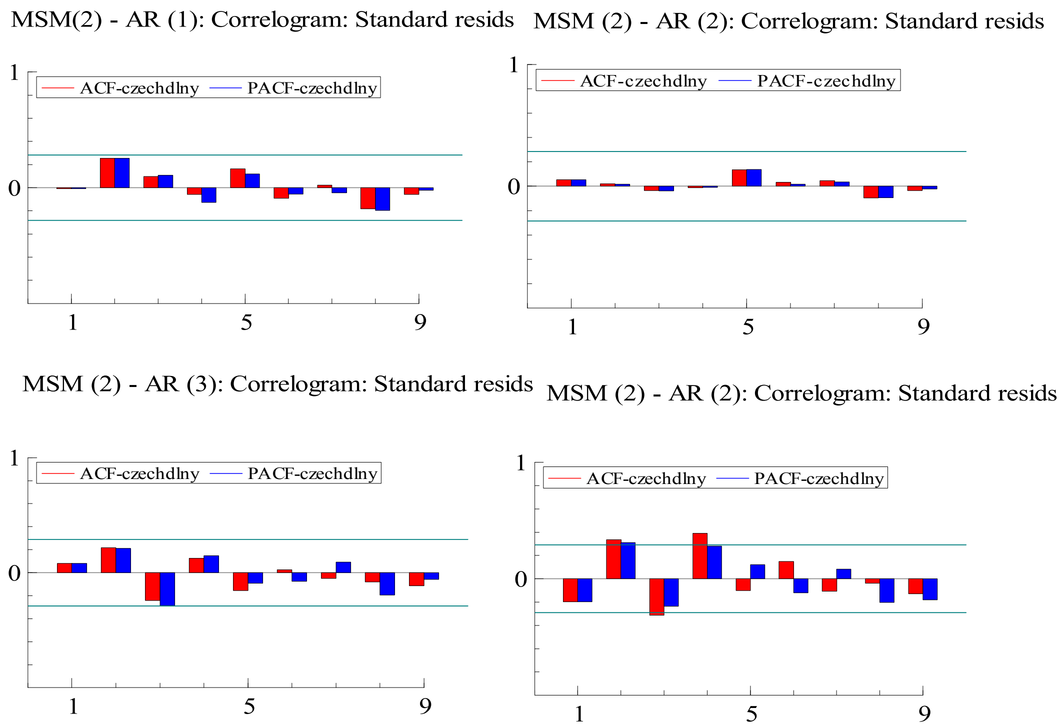

Figure 7-14: Standard residuals analysis for an MSM(2)-AR(1) to MSM(2)-AR(4): Czech Republic

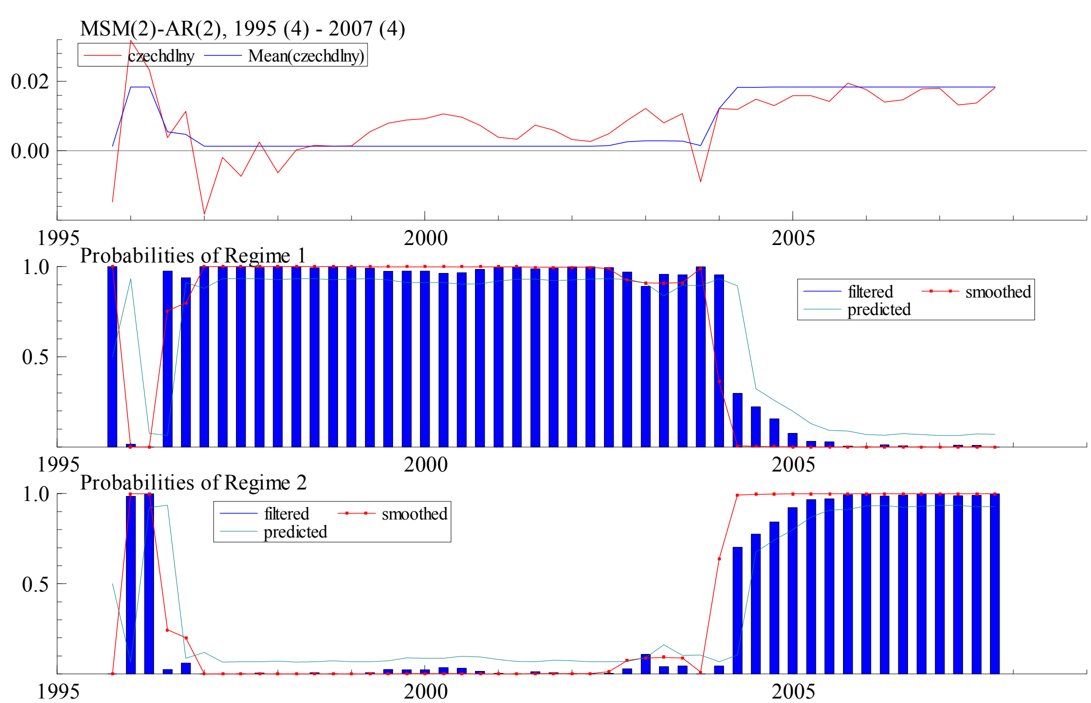

Figure 7-15: Czech Republic regime chronology, GDP data

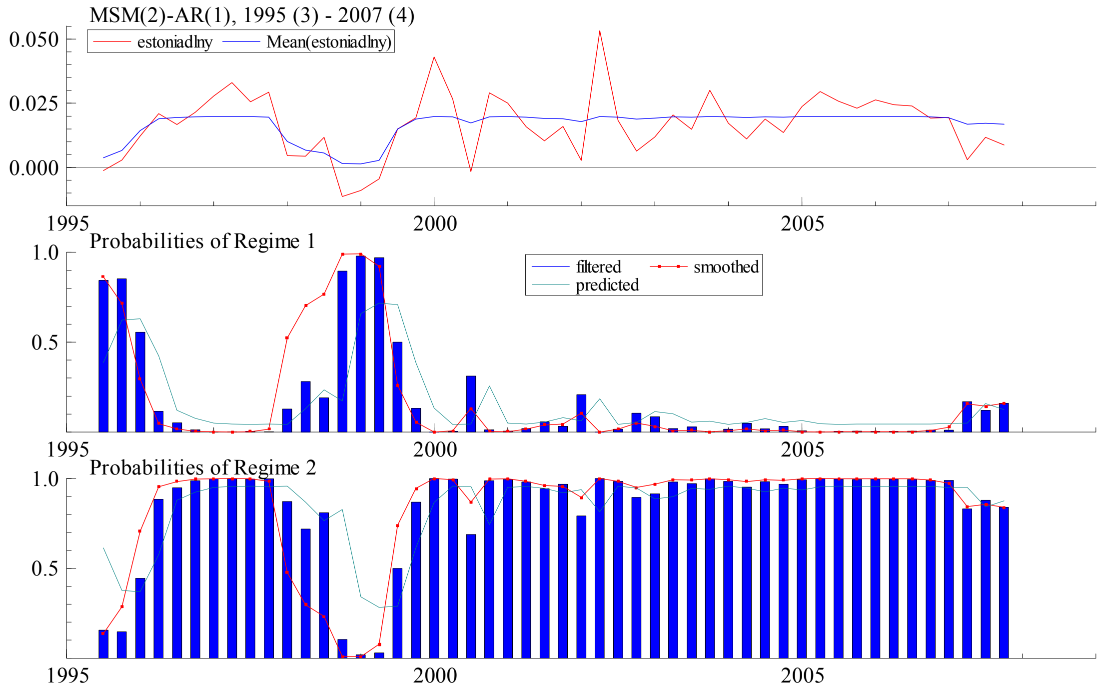

Figure 7-16: Estonia regime chronology, GDP data

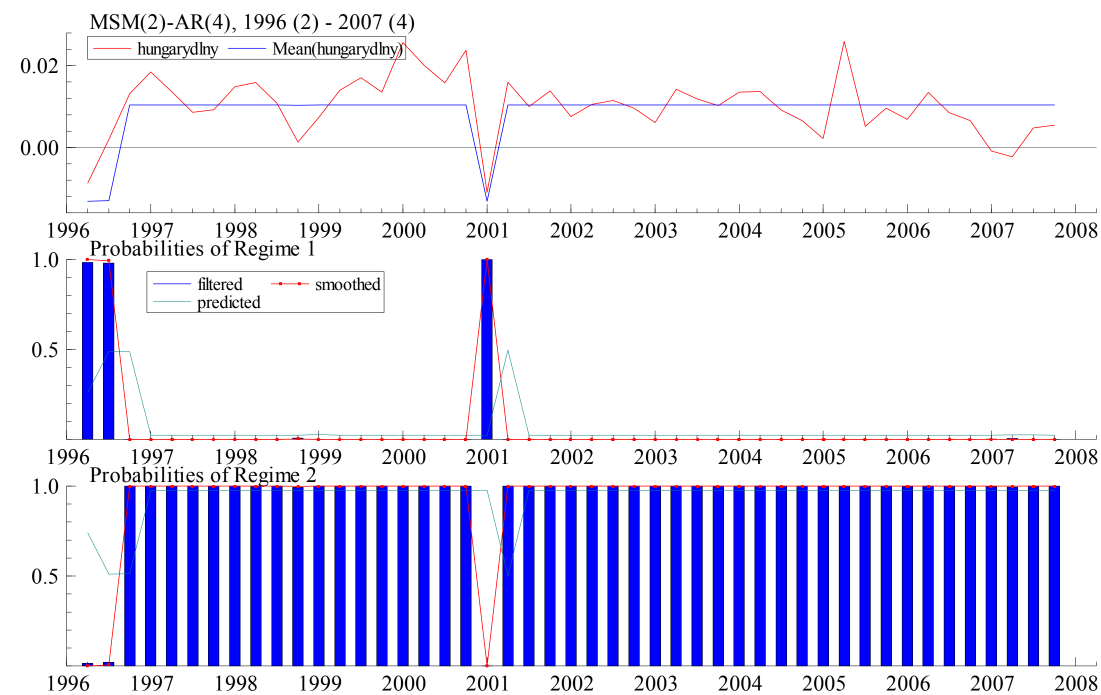

Figure 7-17: Hungary regime chronology, GDP data

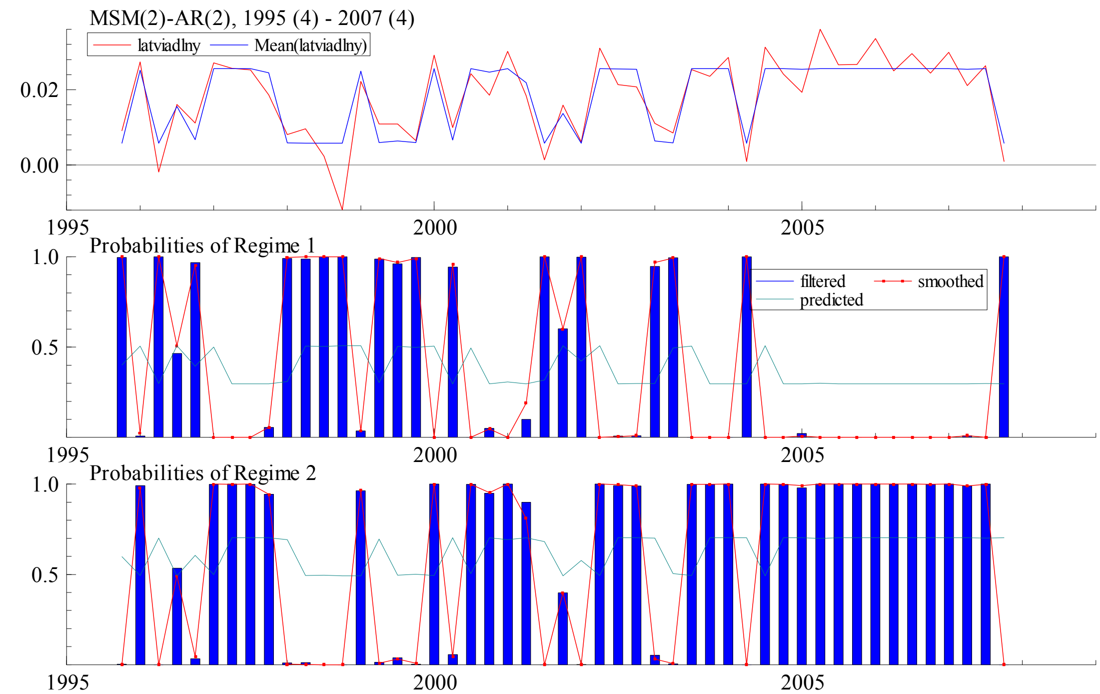

Figure 7-18: Latvia regime chronology, GDP data

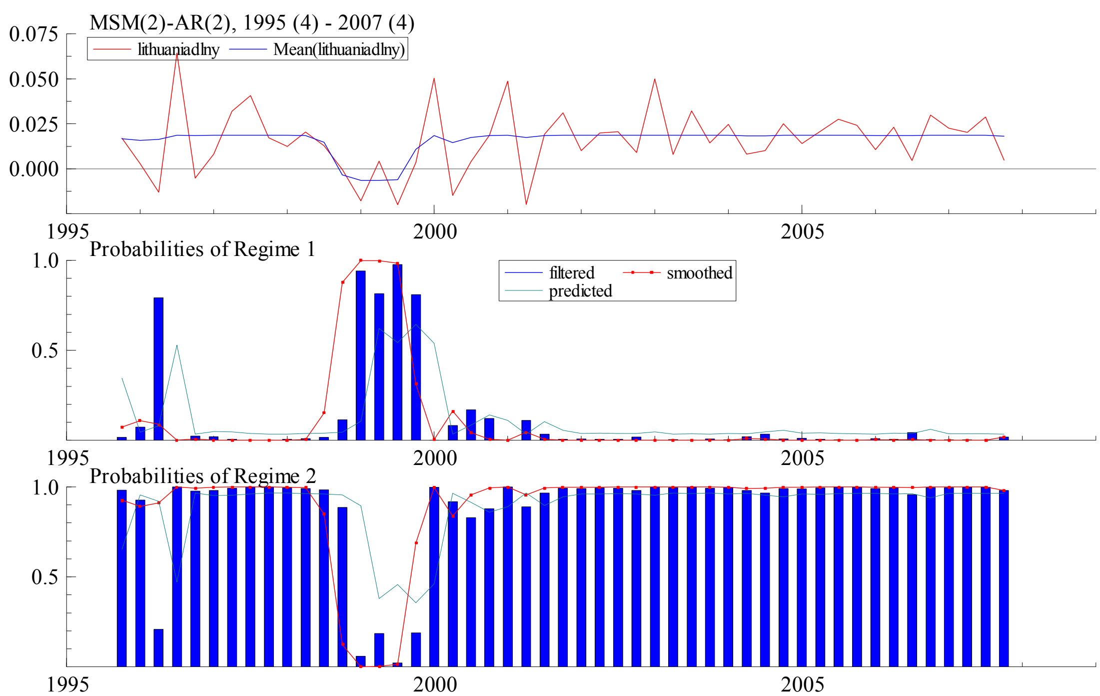

Figure 7-19: Lithuania regime chronology, GDP data

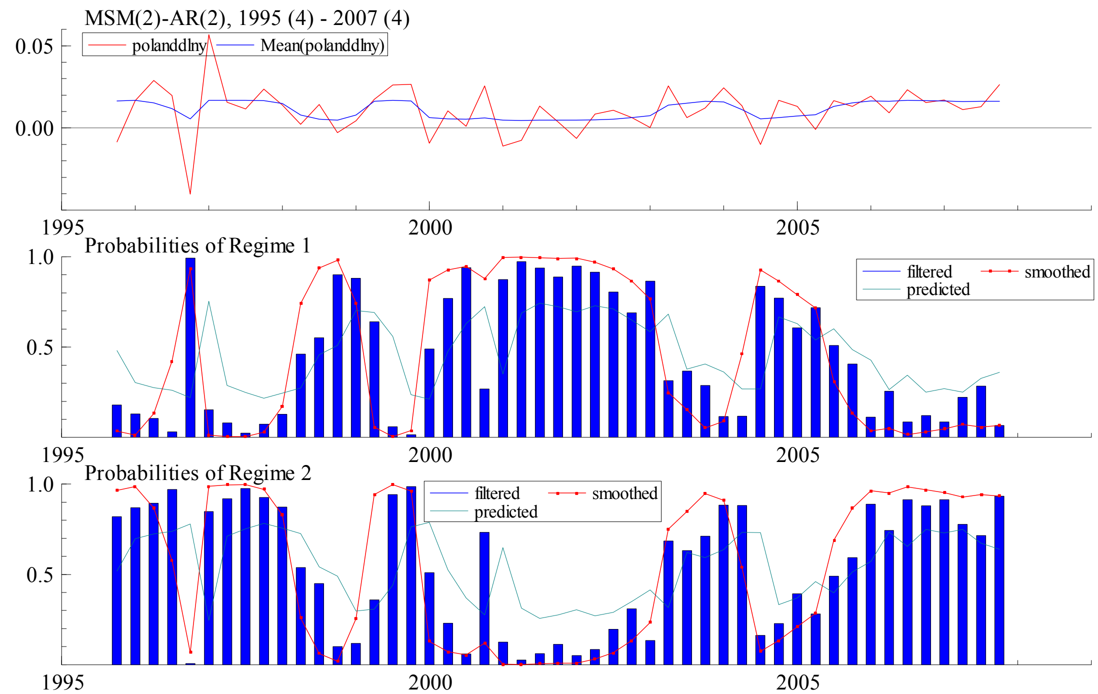

Figure 7-20: Poland regime chronology, GDP data

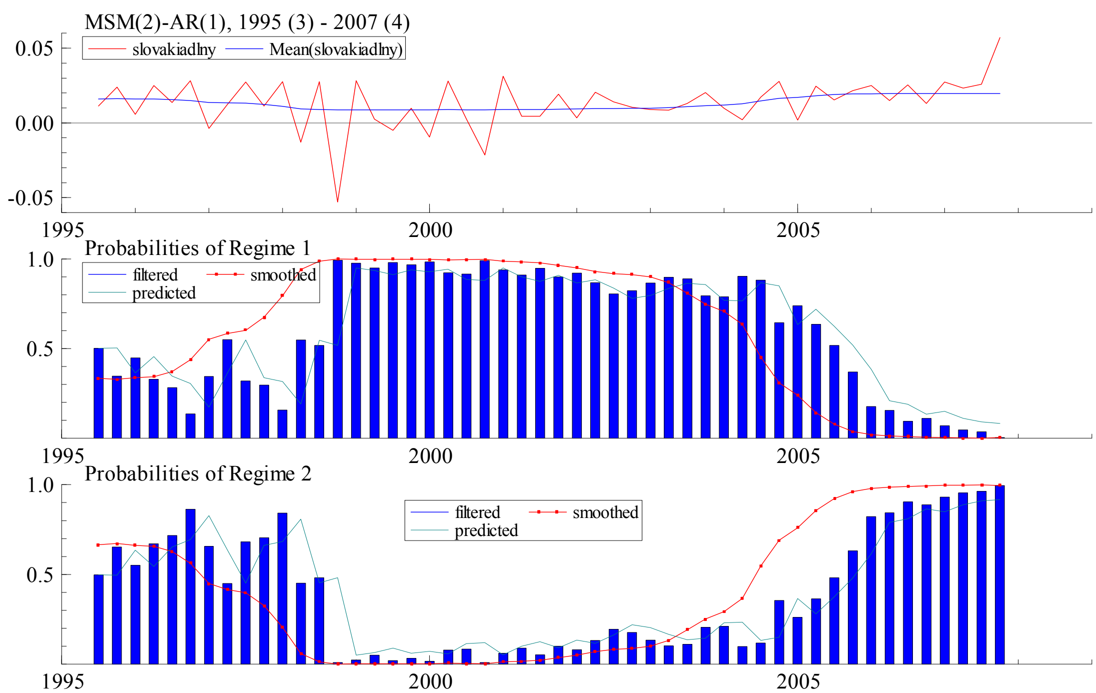

Figure 7-21: Slovak Republic regime chronology, GDP data

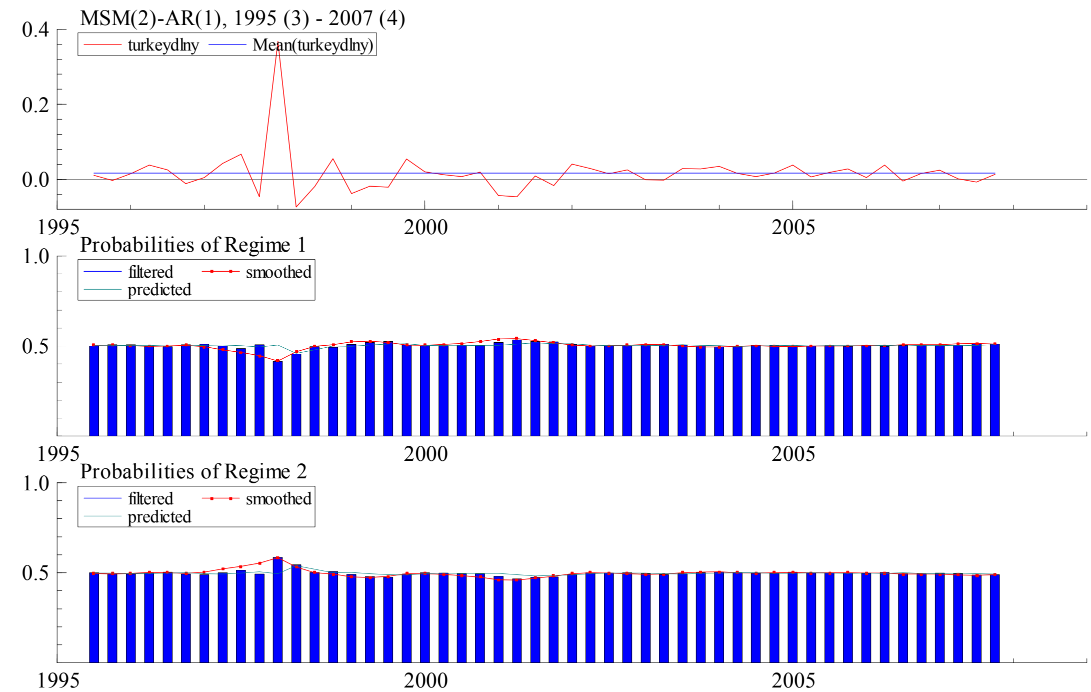

Figure 7-22: Turkey regime chronology, GDP data

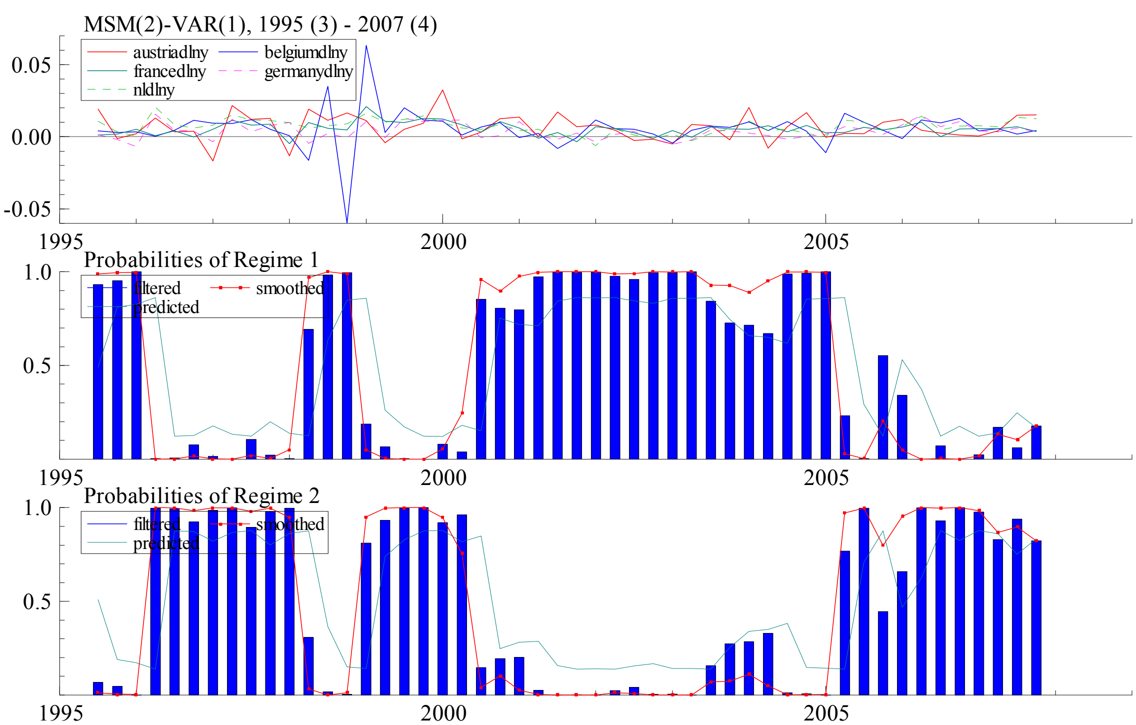

Figure 7-23: Euro Area Core regime chronology, GDP data

7.2 IPI

7.2.1 Data

Units	Scale	Country	Database	Series code	Descriptor	Sample period From:	To:
Index number	Units	Bulgaria	IFS	91866...ZF...	INDUSTRIAL PRODUCTION 2000=100	2000M1	2008M5
Index number	Units	Croatia	IFS	96066...ZF...	INDUSTRIAL PRODUCTION	1991M1	2008M9
Index number	Units	Czech Republic	IFS	93566..CZF...	INDUSTRIAL PRODUCTION S.A	1993M1	2008M7
Index number	Units	Hungary	IFS	94466..CZF...	INDUSTRIAL PRODUCTION SEAS.ADJ.	1989M1	2008M7
Index number	Units	Lithuania	IFS	94666...ZF...	INDUSTRIAL PRODUCTION	1997M1	2008M8
Index number	Units	Macedonia, FYR	IFS	96266...ZF...	INDUST. PRODUCTION 2000=100	1993M1	2006M10
Index number	Units	Poland	IFS	96466..BZF...	INDUSTRIAL PRODUCTION SEAS.ADJ.	1989M1	2008M8
Index number	Units	Romania	IFS	96866...ZF...	INDUST.PRODUCTION	1990M5	2008M8
Index number	Units	Slovak Republic	IFS	93666..BZF...	INDUSTRIAL OUTPUT SEAS.ADJ.	1993M1	2008M8
Index number	Units	Turkey	IFS	18666..BZF...	INDUSTRIAL PRODUCTION SEAS.ADJ.	1989M1	2008M8
Growth rate	Units	Euro Area	IFS	16366..CZF...	INDUSTRIAL PRODUCTION	1998M1	2008M8
Growth rate	Units	Euro Area	Eurostat	0810101	INDUSTRIAL PRODUCTION	1993M1	1999M12
Index number	Units	Austria	IFS	12266..BZF...	INDUSTRIAL PRODUCTION S A	1990M1	2008M8
Index number	Units	Belgium	IFS	12466..CZF...	INDUSTRIAL PROD:SEAS.ADJ	1990M1	2008M7
Index number	Units	France	IFS	13266..CZF...	INDUST PRODUCTION, SEAS ADJ	1990M1	2008M7
Index number	Units	Germany	IFS	13466..CZF...	INDUSTRIAL PROD SA	1990M1	2008M7
Index number	Units	Netherlands	IFS	13866..CZF...	INDUSTRIAL PRODUCTION SA	1990M1	2008M8

Table 7-13: IPI variables' codes and time span

		LN (IPt)				First Difference: LN (IPt) - LN (IPt-1)			
		Constant	Stationery	Constant and Trend	Stationery	Constant	Stationery	Constant and Trend	Stationery
Czech Republic	p-value ADF test	0.9995	X	0.8884	X	0	✓	0.0000	✓
	Constant t-statistic	-1.432501		1.278325		3.400376		-0.171876	
	Trend t-statistic			1.994255				2.20139	
Hungary	p-value ADF test	0.7055	X	0.7074	X	0.0000	✓	0	✓
	Constant t-statistic	1.597755		1.873066		5.833909		3.740188	
	Trend t-statistic			1.660508				-0.912811	
Poland	p-value ADF test	0.7669	X	0.5645	X	0.0000	✓	0.0000	✓
	Constant t-statistic	1.410128		2.155879		6.578026		3.882149	
	Trend t-statistic			1.928377				-0.637328	
Romania	p-value ADF test	0.8588	X	0.8419	X	0.0000	✓	0.0000	✓
	Constant t-statistic	0.663483		1.444627		1.088155		-0.154196	
	Trend t-statistic			1.527627				0.789721	
Slovak Republic	p-value ADF test	0.9939	X	0.7847	X	0	✓	0	✓
	Constant t-statistic	-0.565125		1.641042		4.7295		1.440503	
	Trend t-statistic			1.795397				1.125125	
Turkey	p-value ADF test	0.9024	X	0.9024	X	0.0000	✓	0.0001	✓
	Constant t-statistic	0.499681		0.499681		3.034435		1.042537	
	Trend t-statistic							0.604765	
Austria	p-value ADF test	0.9502	X	0.3731	X	0	✓	0	✓
	Constant t-statistic	0.31868		2.443023		5.126803		2.417376	
	Trend t-statistic			2.421664				0.241899	
Belgium	p-value ADF test	0.6423	X	0.1212	X	0.0000	✓	0.0000	✓
	Constant t-statistic	1.333519		3.073429		2.609442		1.798424	
	Trend t-statistic			2.827861				-0.588838	
France	p-value ADF test	0.3823	X	0.927	X	0.0000	✓	0	✓
	Constant t-statistic	1.83788		1.12202		2.49235		2.543722	
	Trend t-statistic			0.501169				-1.505927	
Germany	p-value ADF test	0.9658	X	0.8058	X	0	✓	0.0000	✓
	Constant t-statistic	-0.032252		1.57217		3.776255		1.156781	
	Trend t-statistic			1.739442				0.891199	
Netherlands	p-value ADF test	0.6976	X	0.015		0	✓	0	✓
	Constant t-statistic	1.171685		3.882928		1.605965		0.966171	
	Trend t-statistic			3.694757				-0.203891	
Euro Area	p-value ADF test					0.0002	✓	0.001	✓
	Constant t-statistic					3.023561		2.537662	
	Trend t-statistic							-1.02366	

Table 7-14:ADF stationarity tests performed to the log of IPI data

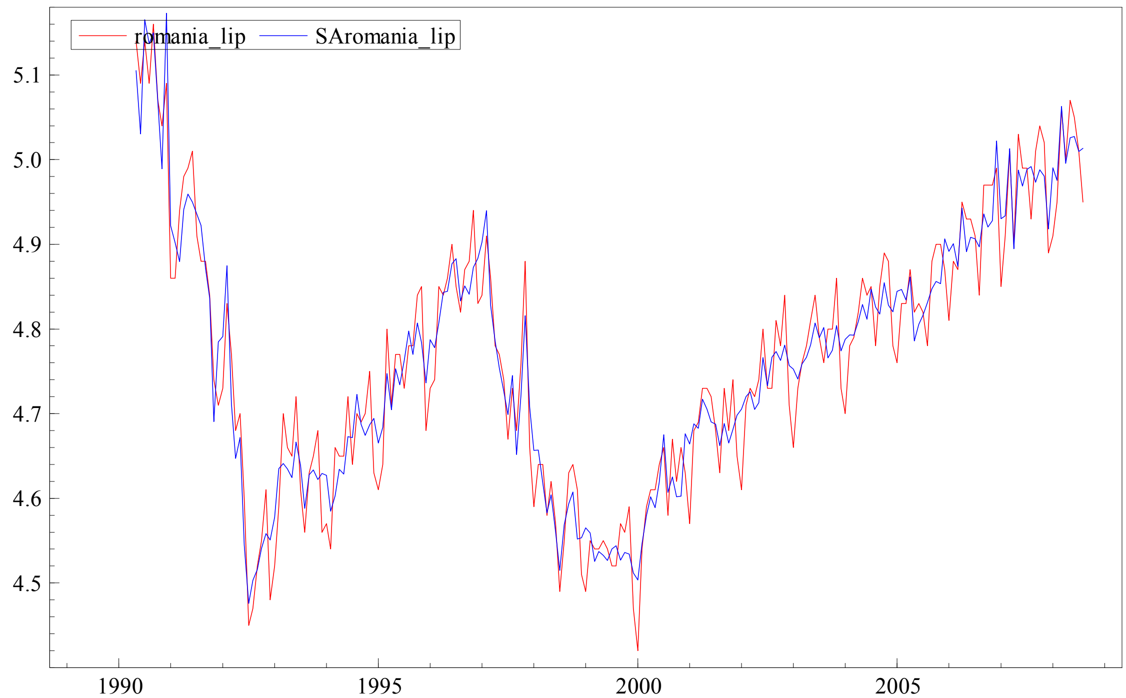

Figure 7-24: Comparison between seasonally and not seasonally adjusted log IPI for Romania

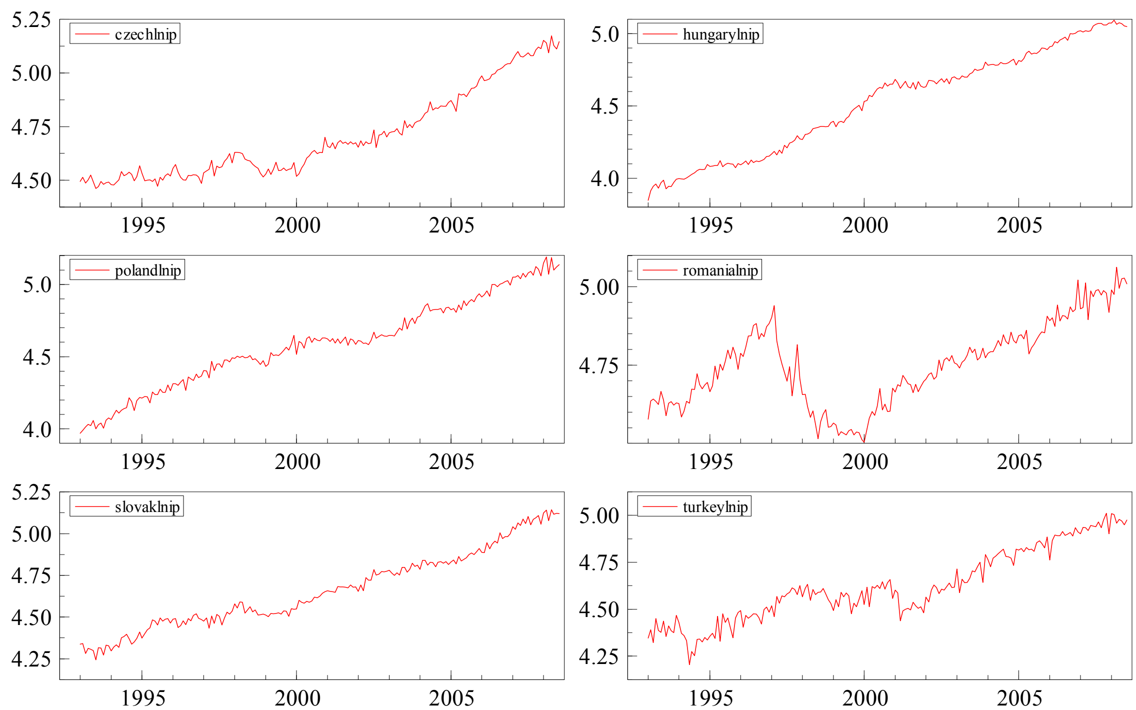

Figure 7-25: log IPI for the Czech Republic, Hungary, Poland, Romania, the Slovak Republic and Turkey

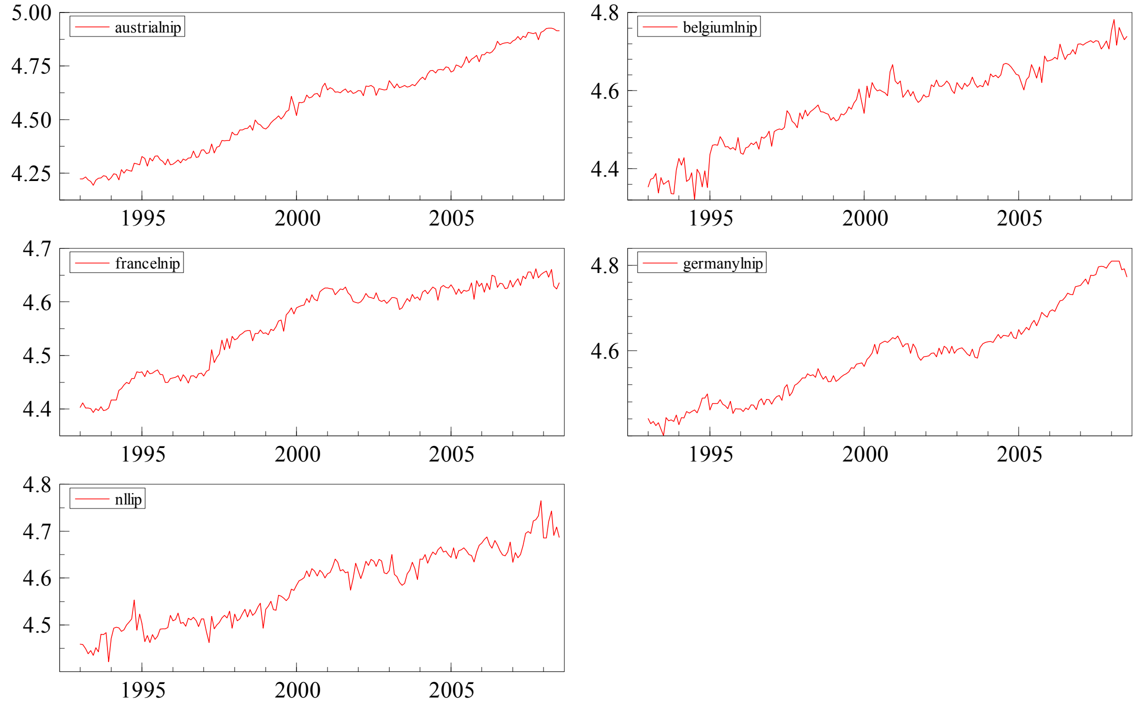

Figure 7-26: log IPI for Austria, Belgium, France, Germany and the Netherlands

7.2.2 MS Regimes

MSMH(2)-AR(2) model of euro_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1993:4 - 1993:7 [0.9367]	1993:8 - 1994:12 [0.940
1995:1 - 1996:7 [0.8631]	1996:8 - 1998:4 [0.8654]
1998:5 - 1999:2 [0.8534]	1999:3 - 2000:12 [0.928
2001:1 - 2002:2 [0.9057]	2002:3 - 2002:4 [0.5680]
2002:5 - 2003:9 [0.8325]	2003:10 - 2004:5 [0.632
2004:6 - 2005:3 [0.7749]	2005:4 - 2007:8 [0.8949]
2007:9 - 2008:7 [0.9205]	

Table 7-15: Regime chronology for the MSMH(2)-AR(2) model of Euro Area, IPI Data. Smoothed probabilities in brackets

MSMH(2)-AR(2) model of czech_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1993:5 - 1993:9 [0.7724]	1993:4 - 1993:4 [0.5546]
1994:1 - 1994:1 [0.5214]	1993:10 - 1993:12 [0.5806]
1994:5 - 1994:6 [0.6592]	1994:2 - 1994:4 [0.5664]
1994:8 - 1995:8 [0.8173]	1994:7 - 1994:7 [0.5447]
1996:1 - 1996:7 [0.8064]	1995:9 - 1995:12 [0.5655]
1996:10 - 1997:6 [0.7981]	1996:8 - 1996:9 [0.5898]
1997:10 - 1999:9 [0.7786]	1997:7 - 1997:9 [0.6025]
1999:11 - 2000:7 [0.6813]	1999:10 - 1999:10 [0.5397]
2000:9 - 2001:5 [0.6794]	2000:8 - 2000:8 [0.5292]
2001:9 - 2001:9 [0.5644]	2001:6 - 2001:8 [0.5443]
2001:11 - 2002:12 [0.6988]	2001:10 - 2001:10 [0.5089]
2003:5 - 2003:10 [0.7460]	2003:1 - 2003:4 [0.5881]
2004:4 - 2004:7 [0.7249]	2003:11 - 2004:3 [0.7080]
2005:1 - 2005:6 [0.7644]	2004:8 - 2004:12 [0.6510]
2005:12 - 2006:2 [0.5790]	2005:7 - 2005:11 [0.6655]
2007:3 - 2007:5 [0.5957]	2006:3 - 2007:2 [0.7516]
2008:1 - 2008:7 [0.8496]	2007:6 - 2007:12 [0.5861]

Table 7-16: Regime chronology for the MSMH(2)-AR(2) model of the Czech Republic, IPI Data. Smoothed probabilities in brackets

MSMH(2)-AR(3) model of hungary_dlip
Estimation sample: 1993 (5) - 2008 (7)

Regime 1	Regime 2
1993:5 - 1993:10 [0.9262]	1993:11 - 1993:12 [0.7925]
1994:1 - 1994:5 [0.8172]	1994:6 - 1994:7 [0.5743]
1994:8 - 1996:10 [0.8941]	1996:11 - 1996:12 [0.5304]
1997:1 - 1997:5 [0.7782]	1997:6 - 1997:10 [0.7175]
1997:11 - 1998:2 [0.7687]	1998:3 - 1998:5 [0.7199]
1998:6 - 1999:5 [0.8579]	1999:6 - 1999:10 [0.8887]
1999:11 - 1999:12 [0.8409]	2000:1 - 2000:7 [0.8744]
2000:8 - 2003:5 [0.9101]	2003:6 - 2003:7 [0.5889]
2003:8 - 2003:10 [0.7473]	2003:11 - 2003:11 [0.5184]
2003:12 - 2005:2 [0.9060]	2005:3 - 2005:4 [0.8925]
2005:5 - 2006:1 [0.8075]	2006:2 - 2006:3 [0.5605]
2006:4 - 2006:8 [0.7201]	2006:9 - 2006:9 [0.5064]
2006:10 - 2007:5 [0.8267]	2007:6 - 2007:7 [0.7141]
2007:8 - 2008:7 [0.9561]	

Table 7-17: Regime chronology for the MSMH(2)-AR(3) model of Hungary, IPI Data. Smoothed probabilities in brackets

MSMH(2)-AR(2) model of poland_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1998:3 - 1998:12 [0.8850]	1993:4 - 1998:2 [0.9649]
2000:7 - 2002:4 [0.9215]	1999:1 - 2000:6 [0.9508]
2002:9 - 2003:2 [0.6959]	2002:5 - 2002:8 [0.8019]
2004:8 - 2005:1 [0.5259]	2003:3 - 2004:7 [0.9273]
	2005:2 - 2008:7 [0.9584]

Table 7-18: Regime chronology for the MSMH(2)-AR(2) model of Poland, IPI Data. Smoothed probabilities in brackets

EQ(1) MSMH(2)-AR(2) model of romania_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1997:2 - 1998:11 [0.9072]	1993:4 - 1997:1 [0.9544]
2006:12 - 2007:6 [0.8983]	1998:12 - 2006:11 [0.9679]
2007:11 - 2008:4 [0.6353]	2007:7 - 2007:10 [0.5445]
	2008:5 - 2008:7 [0.7140]

Table 7-19: Regime chronology for the MSMH(2)-AR(2) model of Romania, IPI Data. Smoothed probabilities in brackets

EQ(1) MSMH(2)-AR(2) model of slovak_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1993:4 - 1993:6 [0.6903]	1993:7 - 1994:7 [0.8308]
1994:8 - 1994:9 [0.5592]	1994:10 - 1995:10 [0.8562]
1995:11 - 1996:3 [0.6119]	1996:4 - 1996:10 [0.7760]
1996:11 - 1997:2 [0.6591]	1997:3 - 1998:3 [0.8527]
1998:4 - 1999:1 [0.7027]	1999:2 - 2001:10 [0.7582]
2001:11 - 2001:12 [0.5540]	2002:1 - 2002:12 [0.8125]
2003:1 - 2003:3 [0.5900]	2003:4 - 2004:4 [0.7881]
2004:5 - 2004:6 [0.5376]	2004:7 - 2008:7 [0.8123]

Table 7-20: Regime chronology for the MSMH(2)-AR(2) model of the Slovak Republic, IPI Data. Smoothed probabilities in brackets

MSMH(2)-AR(2) model of turkey_dlip
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1993:4 - 1994:9 [0.8798]	1994:10 - 1995:2 [0.7601]
1995:3 - 1996:2 [0.9178]	1996:3 - 1996:7 [0.7931]
1996:8 - 1997:4 [0.8303]	1997:5 - 1997:10 [0.7645]
1997:11 - 1998:4 [0.8159]	1998:5 - 1998:9 [0.7447]
1998:10 - 1999:5 [0.8444]	1999:6 - 1999:6 [0.5359]
1999:7 - 2000:6 [0.8184]	2000:7 - 2000:10 [0.5986]
2000:11 - 2001:4 [0.8769]	2001:5 - 2001:10 [0.6709]
2001:11 - 2002:6 [0.8583]	2002:7 - 2002:11 [0.7439]
2002:12 - 2003:2 [0.8571]	2003:3 - 2003:6 [0.7124]
2003:7 - 2004:2 [0.8179]	2004:3 - 2004:7 [0.6396]
2004:8 - 2005:1 [0.8831]	2005:2 - 2005:8 [0.7215]
2005:9 - 2006:4 [0.8159]	2006:5 - 2007:9 [0.8400]
2007:10 - 2008:4 [0.8304]	2008:5 - 2008:7 [0.6011]

Table 7-21: Regime chronology for the MSMH(2)-AR(2) model of Turkey, IPI Data. Smoothed probabilities in brackets

MSMH(2)-VAR(2) model of (austria_dlip,belgium_dlip,france_dlip,germany_dlip,nl_dlip)
Estimation sample: 1993 (4) - 2008 (7)

Regime 1	Regime 2
1993:4 - 1993:6 [0.9629]	1993:7 - 1993:10 [0.7625]
1993:11 - 1993:12 [0.9114]	1994:1 - 1994:2 [0.9274]
1994:3 - 1994:4 [0.7898]	1994:5 - 1994:10 [0.9064]
1994:11 - 1995:11 [0.9233]	1995:12 - 1995:12 [0.5836]
1996:1 - 1997:3 [0.8085]	1997:4 - 1998:6 [0.8915]
1998:7 - 1999:4 [0.8339]	1999:5 - 1999:10 [0.9143]
1999:11 - 2000:2 [0.9919]	2000:3 - 2000:9 [0.8609]
2000:10 - 2002:1 [0.9175]	2002:2 - 2002:6 [0.7793]
2002:7 - 2003:6 [0.9450]	2003:7 - 2004:10 [0.9071]
2004:11 - 2005:2 [0.8766]	2005:3 - 2005:7 [0.8319]
2005:8 - 2005:8 [0.8653]	2005:9 - 2007:11 [0.9440]
2007:12 - 2008:7 [0.9437]	

Table 7-22: Regime chronology for the MSMH(2)-AR(2) model ofthe Euro Area Core, IPI Data. Smoothed probabilities in brackets

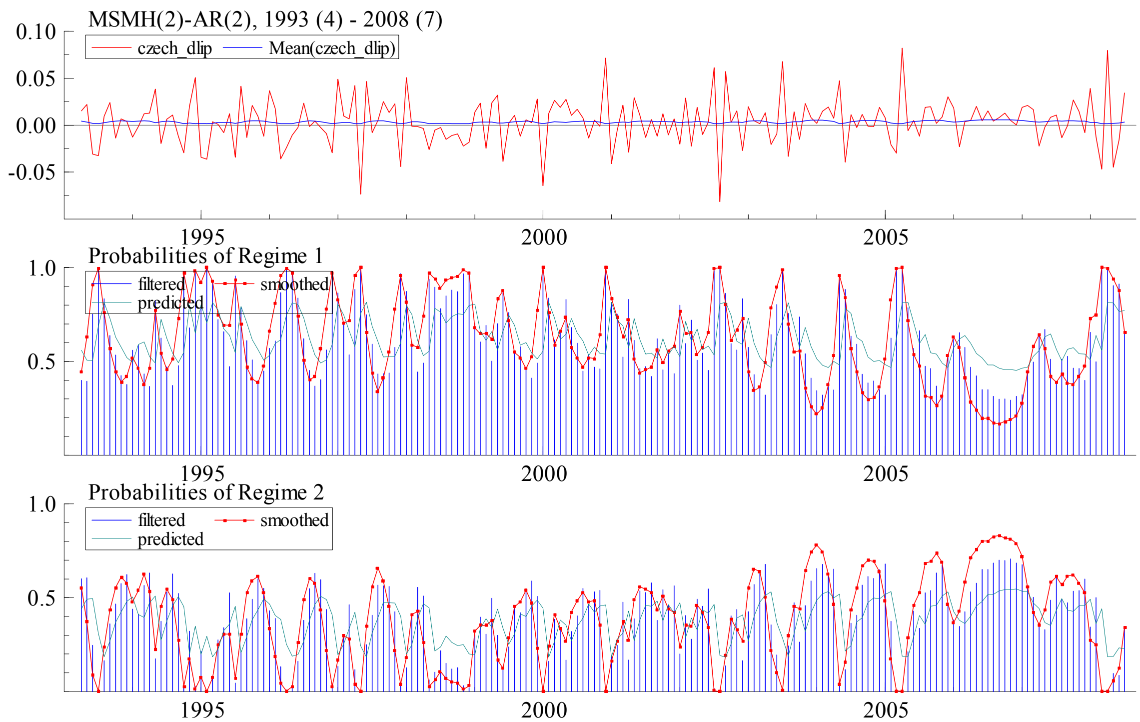

Figure 7-27: Czech Republic regime chronology, IPI data

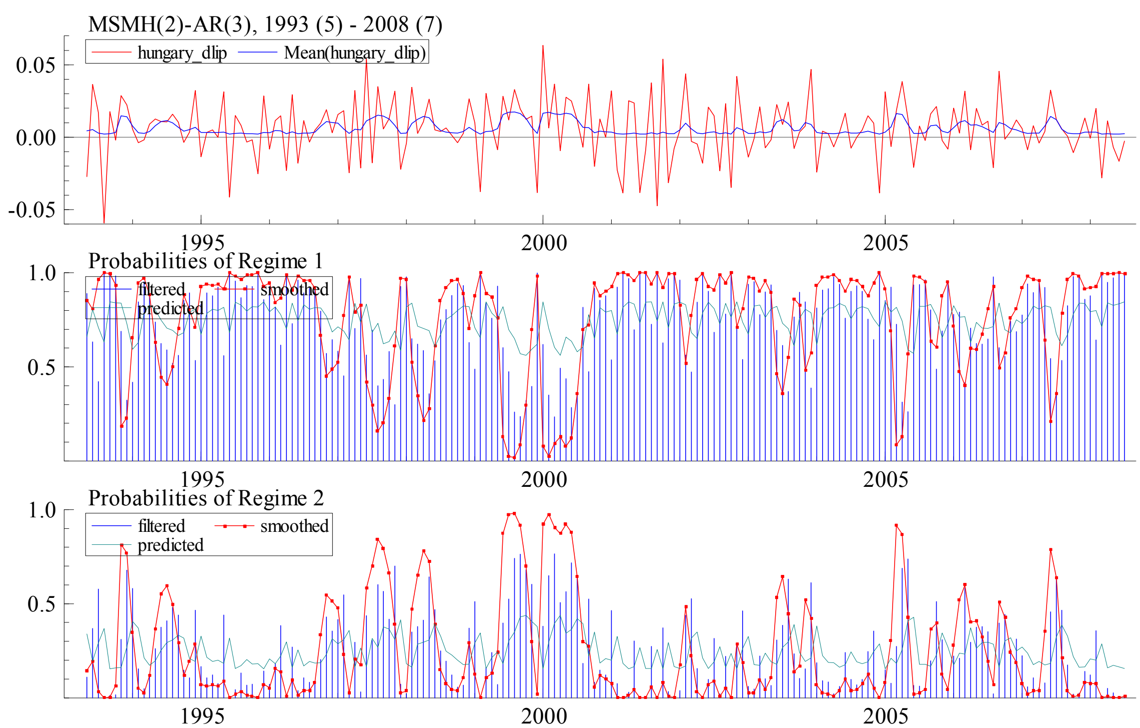

Figure 7-28: Hungary regime chronology, IPI data

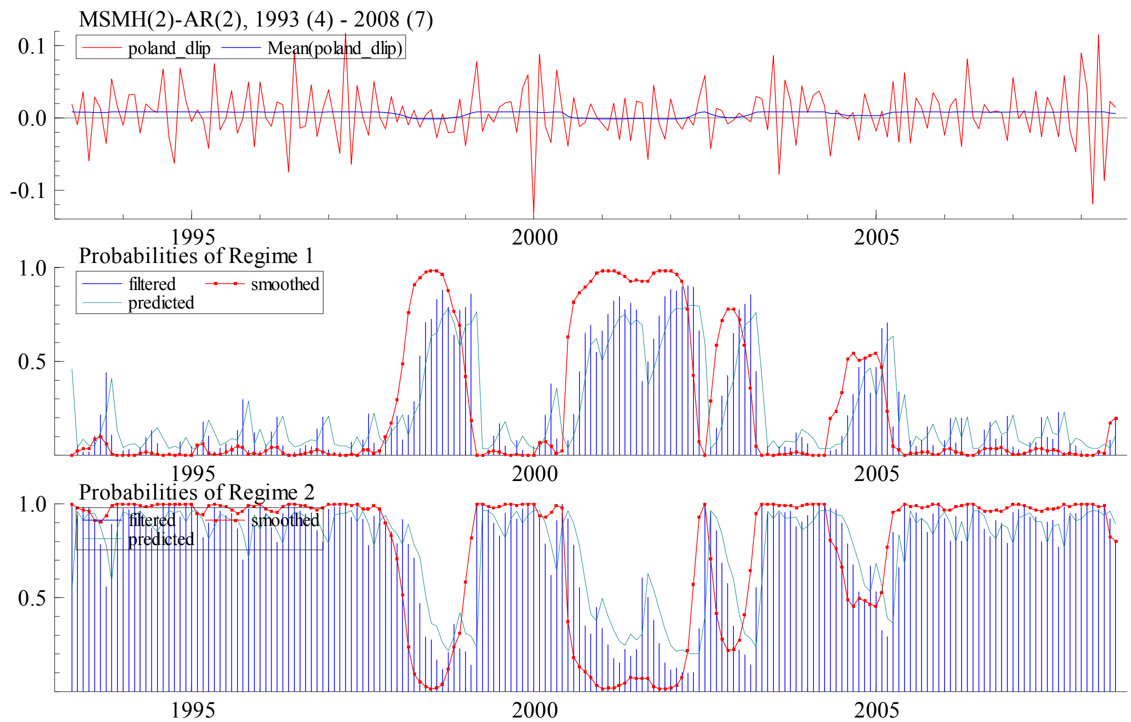

Figure 7-29: Poland regime chronology, IPI data

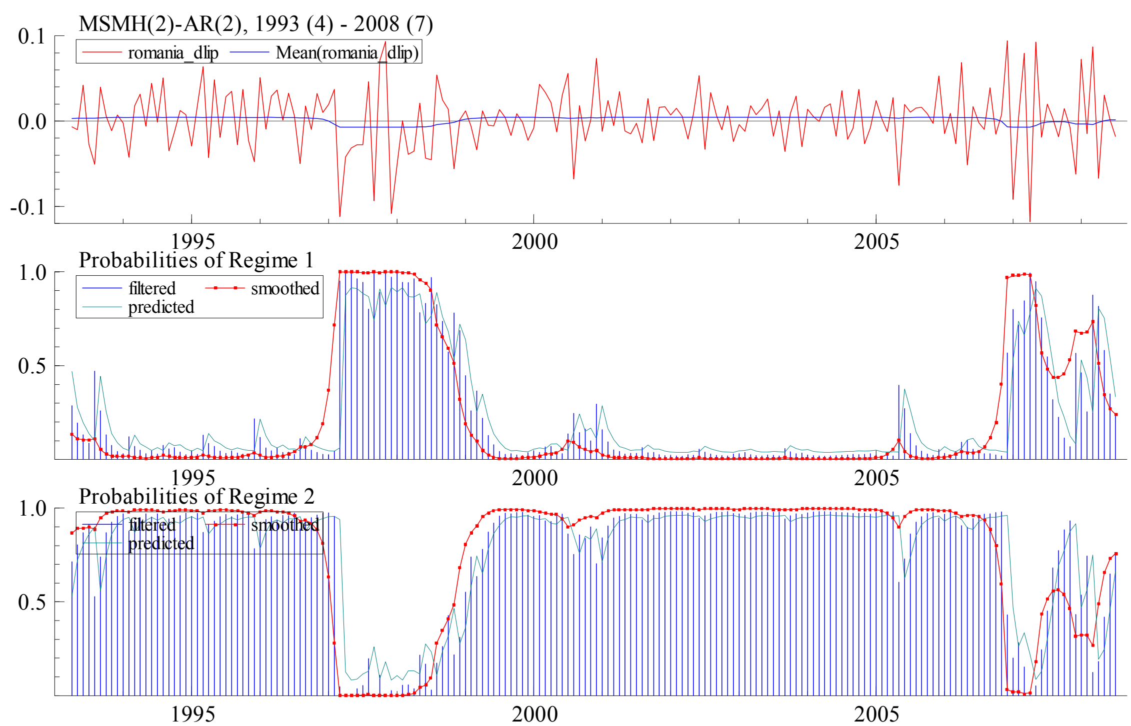

Figure 7-30: Romania regime chronology, IPI data

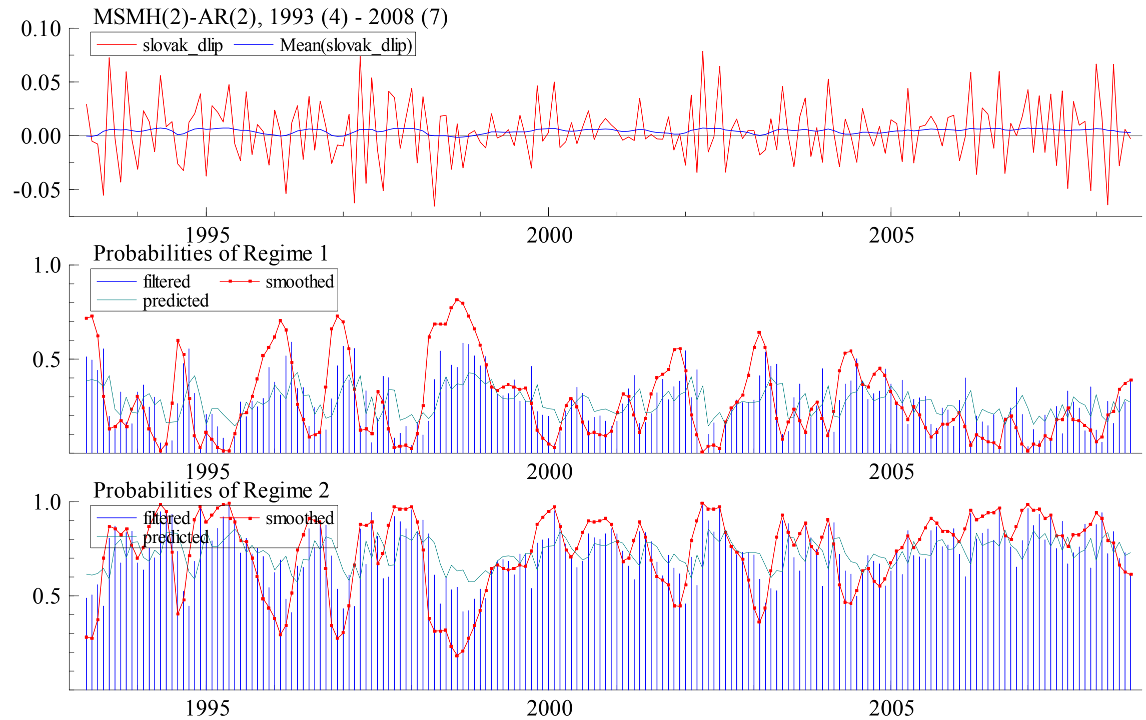

Figure 7-31: Slovak Republic regime chronology, IPI data

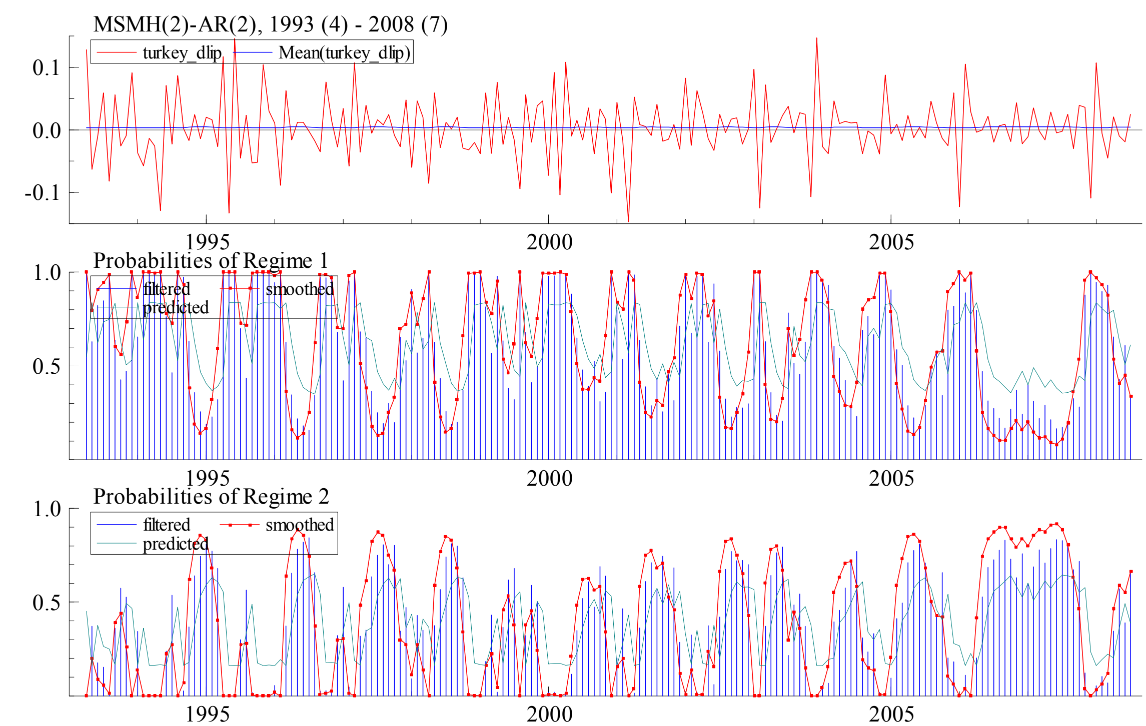

Figure 7-32: Turkey regime chronology, IPI data

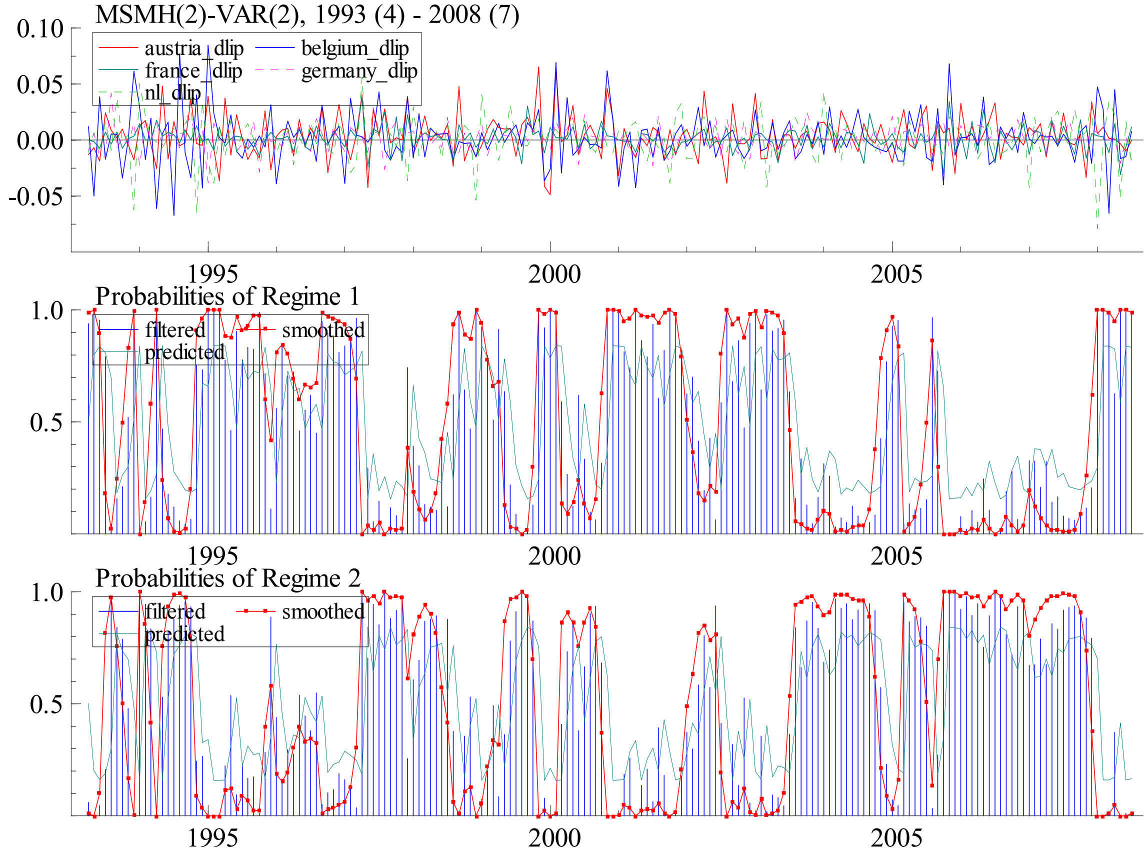

Figure 7-33: Euro Area Core regime chronology, IPI data